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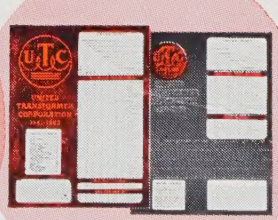

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Radio frequency interference effects such as intermodulation, cross-modulation and desensitization have been plaguing receiver designers for many years. This month, Larry Wright and Joe Aichroth of our Applied Electronics Department describe a passive device that reduces interference effects at microwave frequencies by about 15 db.

A New Device for Microwave Interference Reduction

During an investigation of a low level (—20 to —30 dbm) garnet limiter (see Figure 1) it was found that the device has a frequency-selective limiting property. This property makes the device useful as a passive microwave interference reducer. The basic operation of the limiter was described in a previous AIL advertisement.

This article will emphasize its interference reduction properties.

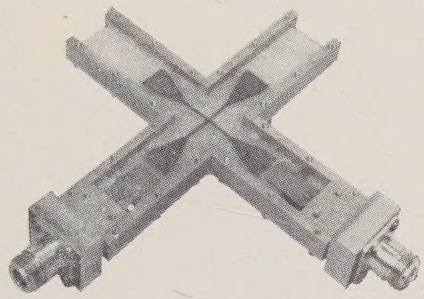

FIGURE 1

The device can be used to reduce the intermodulation, cross-modulation and desensitization produced by a microwave receiver under high input signal levels. In such an application, high level interfering signals are attenuated selectively without changing the low level signal insertion loss. This frequency selective attenuation of a high level interfering signal in the

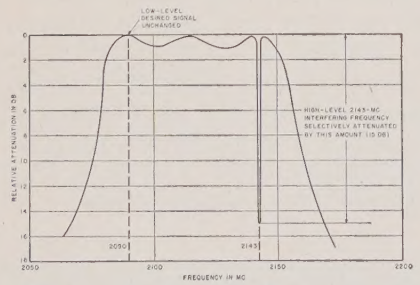

FIGURE 2

presence of a low level desired signal is shown in Figure 2. Note that the presence of the high level signal does not increase the low level insertion loss of the device. The signal to interference ratio is thus greater at the output of the limiter than at the input. Because the power output in the limiting region is relatively low, —25 dbm (see Figure 3), interfering signals can be kept to sufficiently low power levels so that interference in many succeeding devices is reduced below that level

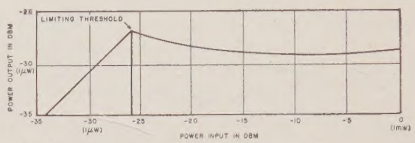

FIGURE 3

which would be generated without the limiter.

The low level insertion loss vs frequency of the limiter shown in Figure 2 was measured using a sweep-frequency modulation technique which permits accurate measurements to be made on very narrow band-width microwave structures—typically less than 0.1% bandwidth. This type of measurement was necessary because the attenuation region around the high level signal is less than 1 mc wide. A detailed picture showing this narrow

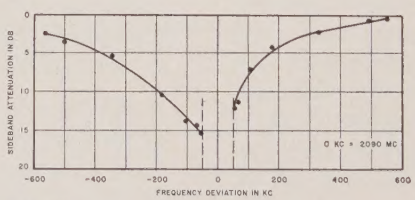

FIGURE 4

attenuation region is shown in Figure 4. The garnet unloaded Q required for such a response is approximately 20,000 which is a remarkable number for a resonator only .060″ in diameter. Because this "rejection notch" characteristic is so narrow, most of the low level passband is unaffected by the high level signal. There will be no significant change in the low level desired signal unless the interfering signal is closer than about 1 mc to the desired signal.

Situations have been observed where two or more high level interfering signals have been within the low level passband. It has been observed that the limiter produces a separate and very narrow band rejection region around each of these high level signals. Because each response is quite narrow, several separate in-band high level signals may be simultaneously attenuated without disturbing a desired low level signal.

In order to be useful as an interference reducer, the limiter must produce little interference of its own. Measurements of the interference characteristics indicate that the self-generated interference levels are below those normally encountered in associated devices.

This device can be used in front of a parametric amplifier to reduce the susceptibility of the amplifier to nonlinear interference phenomena by about 15 db. The filter characteristics of the limiter also reduce pump and idler leakage, and the spurious responses associated with idler and sum frequency inputs. This frequency selective limiting characteristic can be used for reduction of interference in many other devices whose interference thresholds are in the —30 to +10 dbm region. Although only the interference reduction properties of the device have been discussed here, many other uses for this novel effect exist and may occur to the reader.

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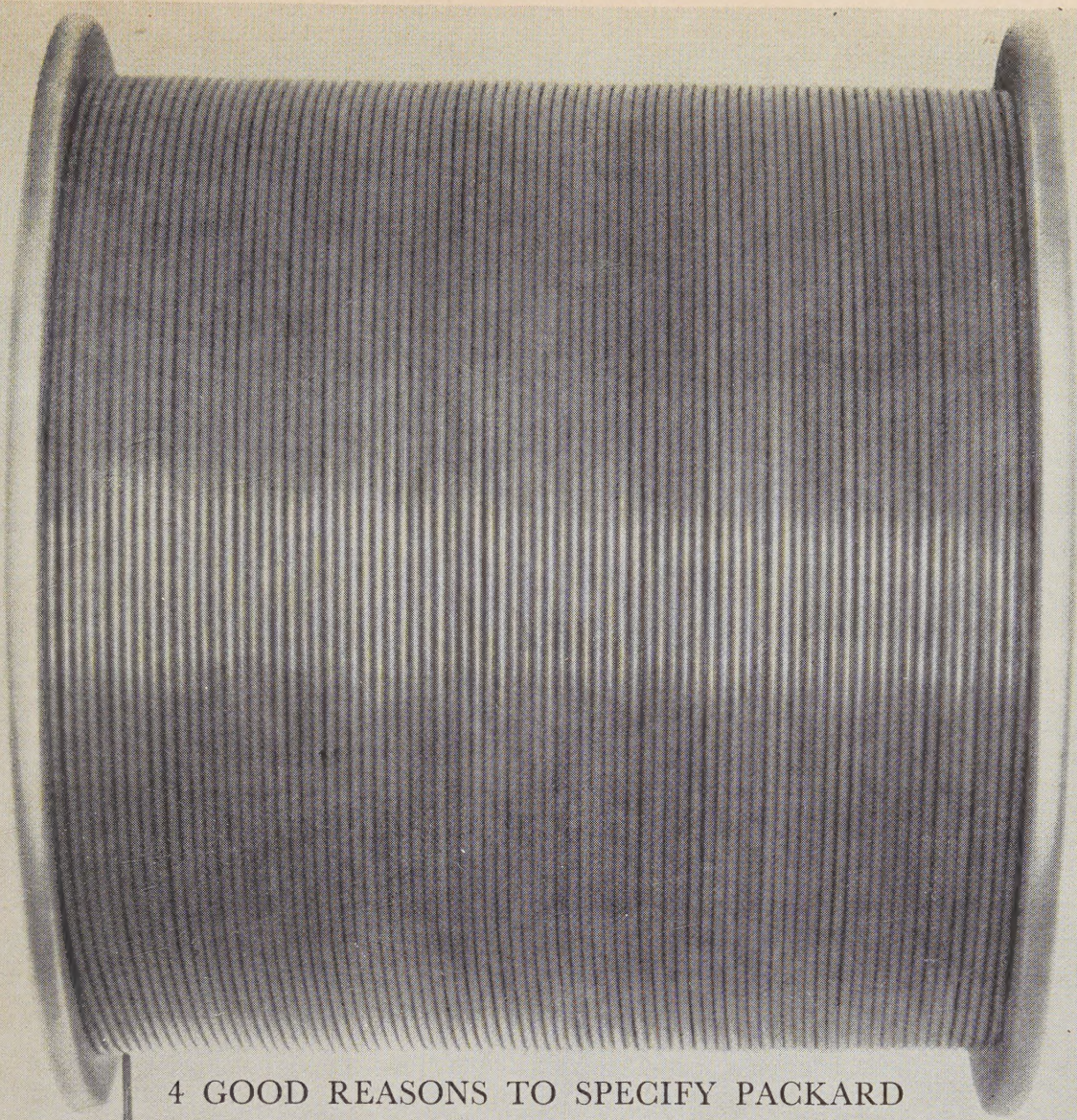

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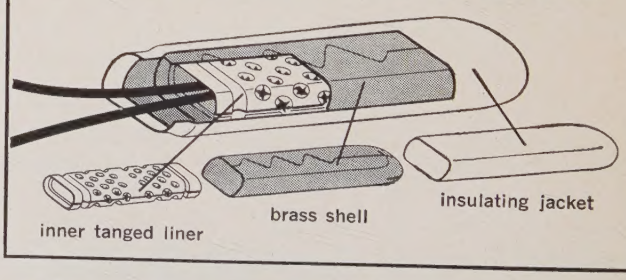

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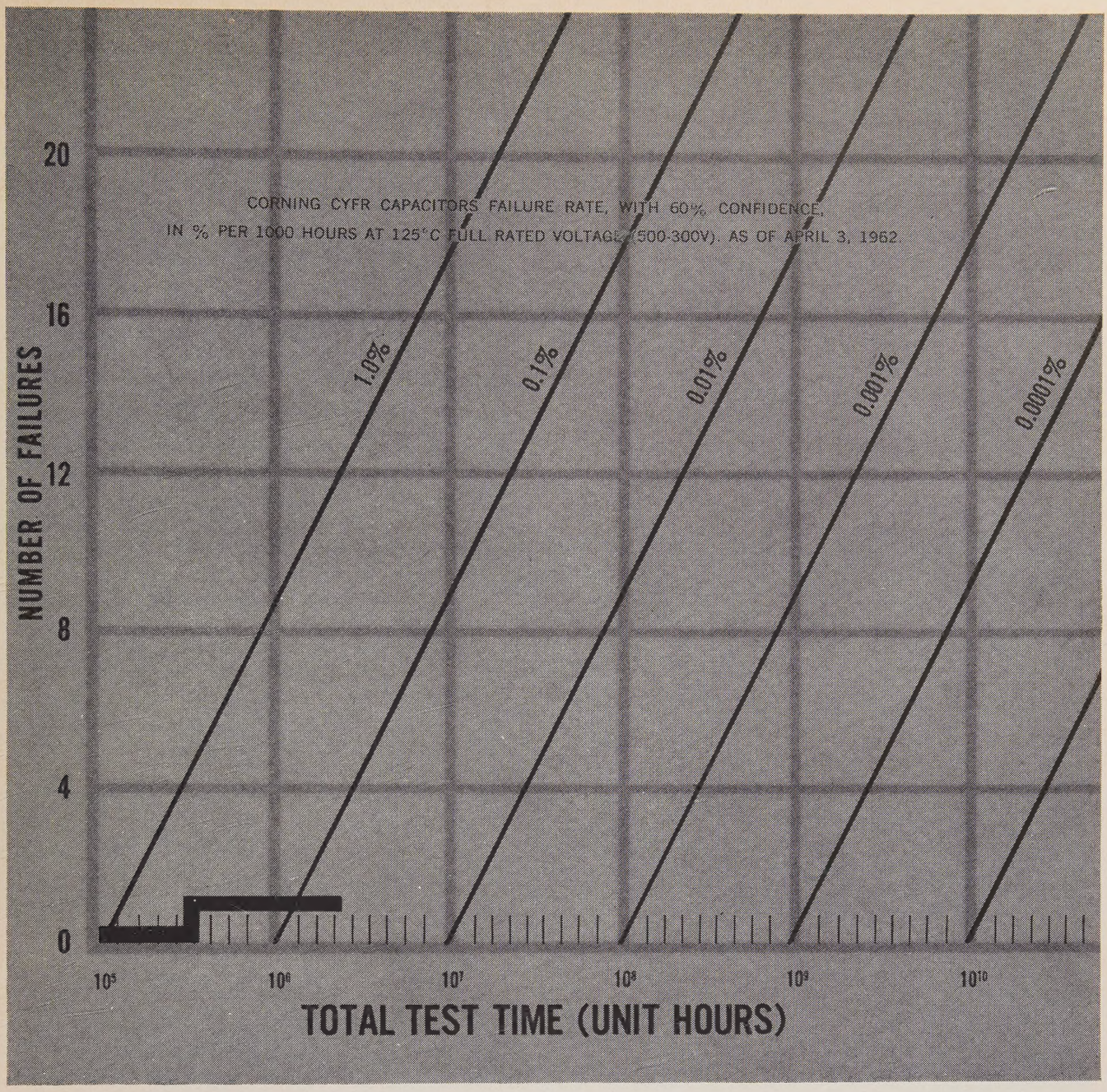

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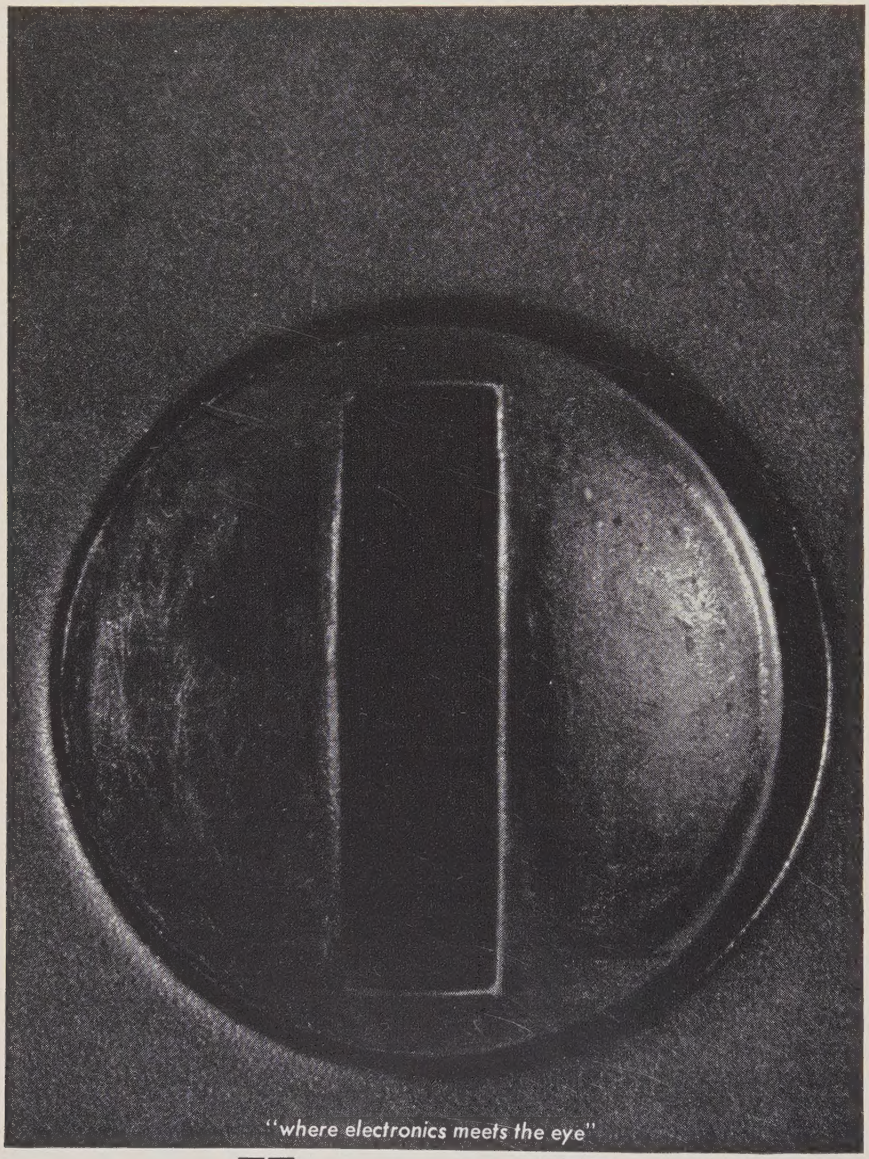

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Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups, which include exhibits.

△

June 12-14, 1962

Armed Forces Communications & Electronics Show, Sheraton Park Hotel, Washington, D.C.

Exhibits: Mr. William C. Copp, 72 W. 45th St., New York 36, N.Y.

June 18-19, 1962

Chicago Spring Conference on Broadcast and Television Receivers, O'Hare Inn, Chicago, Ill.

Exhibits: Mr. John H. Landeck, Admiral Corp., 3800 W. Cortland St., Chicago 47, Ill.

June 25-27, 1962

Sixth National Convention on Military Electronics, Shoreham Hotel, Washington, D.C.

Exhibits: Mr. L. D. Whitelock, 5614 Greentree Rd., Bethesda 14, Md.

August 21-24, 1962

Western Electronics Show and Conference (WESCON), Statler-Hilton Hotel & Memorial Sports Arena, Los Angeles, Calif.

Exhibits: Mr. Don Larson, WESCON, 1435 S. La Cienega Blvd., Los Angeles, Calif.

August 29-September 1, 1962

Second International Conference on Information Processing, Munich, Germany

Exhibits: Dr. Heinz Billing, Max Planck Institute, Munich, Germany

September 3-7, 1962

National Advanced Technology Management Conference, Opera House, Seattle World's Fair Grounds, Seattle, Wash.

Exhibits: Mr. Hugh Fairclough, 1624 22nd Avenue East, Seattle 2, Wash.

October 1-3, 1962

Eighth National Communications Symposium, Hotel Utica & Utica Municipal Auditorium, Utica, N.Y.

Exhibits: Mr. Charles Glaviano, 45 Meadow Dr., Rome, N.Y.

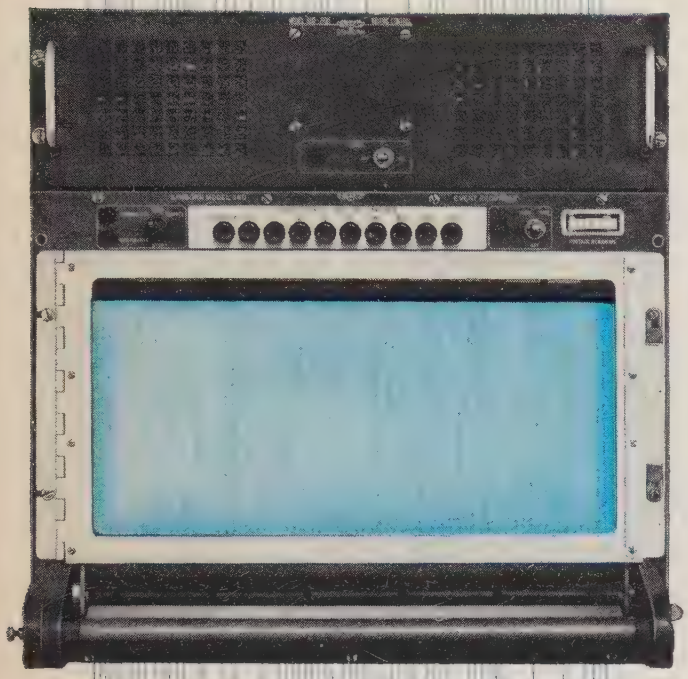
October 2-4, 1962

Seventh National Symposium on Space Electronics & Telemetry, Fontainebleau Hotel, Miami Beach, Fla.

Exhibits: Mr. Charles H. Doersam, Jr., Instruments for Industry, 101 New South Road, Hicksville, L.I., N.Y.

(Continued on page 10A)

Sanborn 120-Channel Event Recording System:



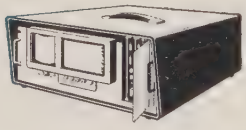
$4,875 Complete With Writing Control*

THE SANBORN SERIES "360" System provides sharp, clear traces of on/off events as brief as 1.3 milliseconds, instantly recorded on a 16-inch, dry process, electrically-sensitive chart. Pulsed writing makes the traces easily readable at any of the 18 chart speeds (9 standard, 9 more optional), reduces power consumption and extends the life of the styli.

Key to fast system response is the Sanborn Model 360-2100 Writing Control used with the Recorder. This optional "electronic relay" switches styli voltages faster than relays or switches, and at lower cost than solid-state devices. Four plug in cables connect the Writing Control to the Recorder. RF shielding allows the Recorder to meet the requirements of many military applications.

Only 19¼" of panel space is required for the complete system, including blowers. Servicing is easy because of Sanborn modular design — each bank of 30 styli may be pulled out and an individual stylus replaced by plugging in a new one. Stylus life is doubled by two-side design — a worn stylus is simply turned over and the other side used.

As in oscillographic recording, Sanborn has probably already designed your custom event recording system. Ask Sanborn for information on the wide variety of choices available — electric writing 30 to 120 channels, portable or rack-mounted, tube, transistor or relay writing control. Heated stylus combination event and oscillographic recording systems with vertical or horizontal paper drive. Call your Sanborn industrial Sales-Engineering Representative — offices in principal cities throughout the U. S., Canada and foreign countries.



30-CHANNEL PORTABLE — complete on/off event recording system Model 361 with integral, fully transistorized writing control. The 361 can be portable, as shown, or rack-mounted. The 361R rack-mounted 30-channel system requires only 8¾" of panel space.

*Price FOB Waltham, Mass. and subject to change without notice. Add state and local taxes where applicable. 120-Channel Recorder without Writing Control, $3,900. Special 30-, 60- and 90-channel event recorders and writing control units also available, which can be later converted to 120 channels.

INDUSTRIAL DIVISION

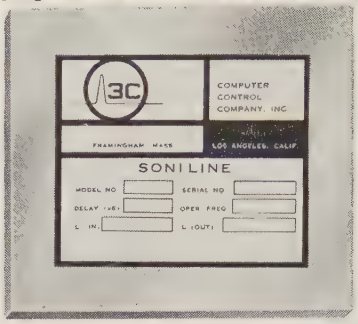
SANBORN COMPANY

WALTHAM 54, MASSACHUSETTS

A Subsidiary of Hewlett-Packard Company

CAPABILITY REPORT:

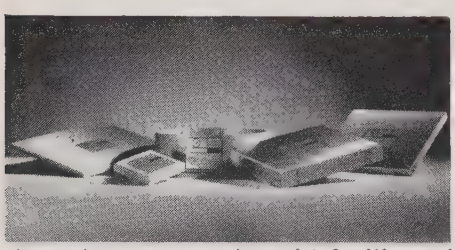
MAGNETOSTRICTIVE DELAY LINES



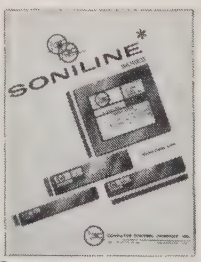
Computer Control Company, Inc. is pleased to announce the availability of the **Soniline Magnetostrictive Delay Lines** listed below. Designed for maximum reliability and utility, these new **Sonilines** are distinguished by top quality construction and precise operating performance — the specific result of 3C's rigid quality control and manufacturing procedures. **Initial quantities of these Sonilines are available for delivery in less than 30 days!**

Soniline Model No.	Delay Range μsec	Maximum Input Pulse Repitition Freq.	Temperature Coefficient of Delay or Drift
S-33	4 — 14	1-2 MC (RZ) 2-4 MC (NRZ)	$\pm 5 \cdot 10^{-9}$ sec 0-80°C
S-66A S-66B S-66C S-66D	20 — 100 101 — 500 501 — 1000 1001 — 1500	1 MC (RZ)	±0.1 μsec 0-50°C
S-66E	1501 — 2000	1 MC (RZ)	±0.1 μsec 0-50°C
S-88A	2001 — 2400	1 MC (RZ)	±0.1 μsec 0-50°C
S-88B	2401 — 4000	500 KC (RZ)	5 ppm/°C
S-88C	2401 — 6000	1 MC (RZ)	±0.1 μsec 20-40°C
S-88D	5000 — 10,000	500 KC (RZ)	5 ppm/°C
S-88E	10,000 — 15,000	500 KC (RZ)	5 ppm/°C
S-99A S-99B S-99C S-99D	20 — 100 101 — 350 351 — 600 601 — 2000	2 MC (NRZ)	±0.1 μsec 0-50°C

For unique application requirements, 3C designs and manufactures special **Soniline** models to meet your specific needs. We solicit your inquiries.



Shown above are several special **Sonilines** of various sizes and configurations.



For additional information, ask for our new **Soniline** brochure!

3C

PRODUCT DIVISION

H-PACS/S-PACS/T-PACS/MIL-PACS/CORE MEMORIES/DICOTRONS/SONILINES

COMPUTER CONTROL COMPANY, INC.

EASTERN PLANT: 983 CONCORD STREET/FRAMINGHAM/MASSACHUSETTS

WESTERN PLANT: 2251 BARRY AVENUE/LOS ANGELES 64/CALIFORNIA

Meetings with Exhibits

(Continued from page 8A)

October 8-10, 1962

National Electronics Conference, McCormick Place, Chicago, Ill.

Exhibits: Mr. Rudy Napolitan, National Electronics Conference, 228 N. LaSalle St., Chicago, Ill.

October 15-18, 1962

Symposium on Space Phenomena & Measurement, Statler-Hilton Hotel, Detroit, Mich.

Exhibits: Mr. J. B. Bullock, University of Michigan, Ann Arbor, Mich.

November 1-2, 1962

Sixth National Conference on Product Engineering and Production, Jack Tar Hotel, San Francisco, Calif.

Exhibits: Mr. W. Dale Fuller, Lockheed Missiles & Space Div., P.O. Box 504, Sunnyvale, Calif.

November 4-7, 1962

Fifteenth Annual Conference on Electronic Techniques in Medicine & Biology, Conrad Hilton Hotel, Chicago, Ill.

Exhibits: Professional Associates, Inc., 6520 Clayton Rd., Saint Louis 17, Mo.

November 5-7, 1962

NEREM (Northeast Research & Engineering Meeting), Commonwealth Armory & Somerset Hotel, Boston, Mass.

Exhibits: Mr. S. K. Gibson, Instruments of New England, 108 Greenwood Lane, Waltham 5, Mass.

November 12-15, 1962

Eighth Annual Conference on Magnetism & Magnetic Materials, Penn-Sheraton Hotel, Pittsburgh, Pa.

Exhibits: Mr. J. L. Whitlock, John Leslie Whitlock Associates, 253 Waples Mill Rd., Oakton, Va.

November 16-17, 1962

Communications Symposium, Queen Elizabeth Hotel, Montreal, P.Q., Canada

Exhibits: Mr. Arthur H. Gregory, Northern Electric Co., Ltd., 1600 Dorchester Blvd. W., Montreal, P.Q., Canada

November 19-20, 1962

MAECON (Mid-America Electronics Conference), Continental Hotel, Kansas City, Mo.

Exhibits: Dr. Arthur Goldsmith, Wilcox Electric Co., 1400 Chestnut, Kansas City 27, Mo.

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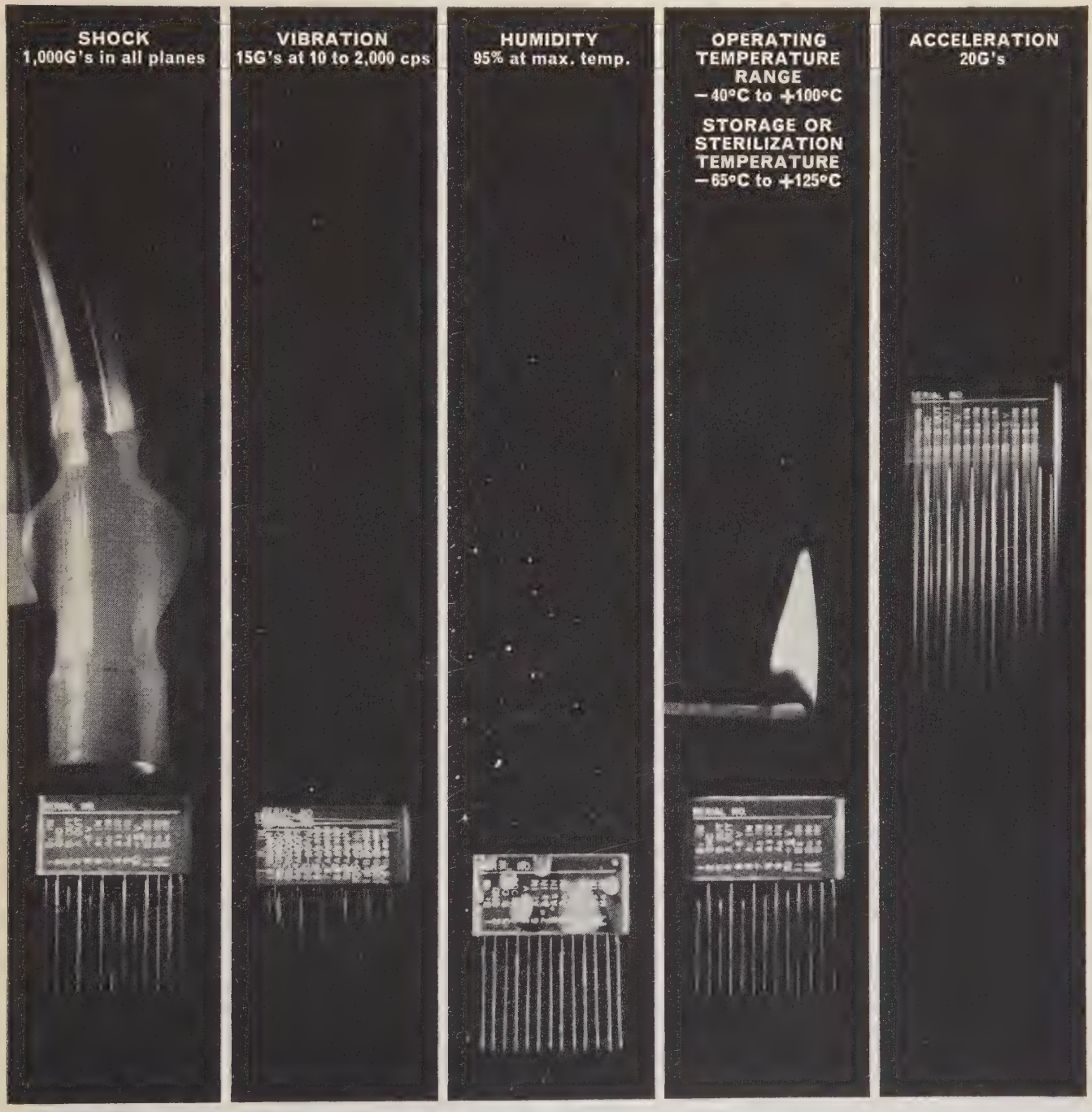
Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

LOW POWER SILICON DIGITAL MODULES

ENVIRONMENTALLY PROVED . . . AVAILABLE NOW!

Delco Radio's new silicon digital modules operate on less than 4 mw. of power per logic stage. They are rugged enough to withstand extreme environmental conditions and are small and lightweight. Encapsulated in light foamy epoxy, each module weighs less than 12 grams and occupies less than one-half cubic inch. The basic set of modules includes a bistable multivibrator, a diode NOR gate, a power driver, a monostable multivibrator and an astable multivibrator. From these basic units larger computer subassemblies can be assembled, such as shift registers, adders, binary counters, decimal counters and timing devices. A range of applications—from small scale switching circuits to large computers can be satisfied with these modules. Environmentally proved to:



Data sheets are available. Just write or call our Military Sales Department.

Physicists and electronics engineers: Join Delco Radio's search for new and better products through Solid State Physics.

PIONEERING ELECTRONIC PRODUCTS THROUGH SOLID STATE PHYSICS

DELCO RADIO

Division of General Motors • Kokomo, Indiana

1962 IRE INTERNATIONAL CONVENTION

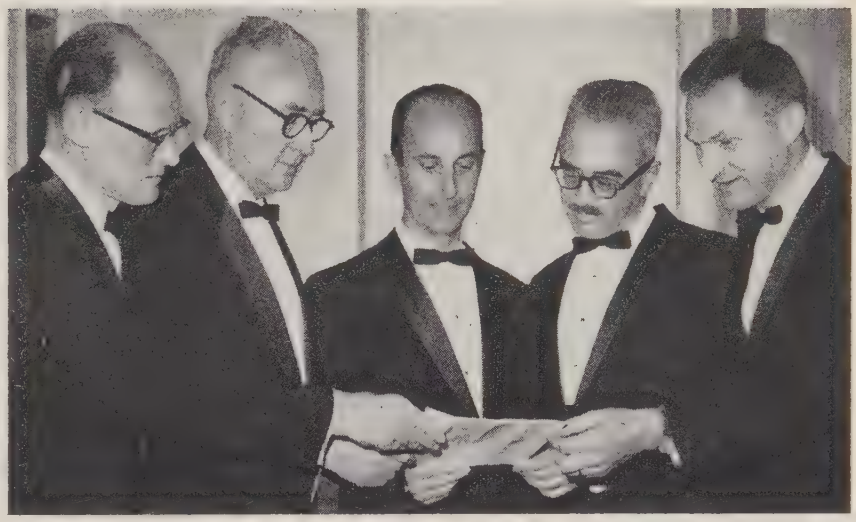
Alfred N. Goldsmith, IRE Founder, cutting the ribbon marking the opening of the Golden Anniversary International IRE Convention, with P. E. Haggerty, IRE President and George W. Bailey, Convention Chairman.

(*Below*) a view of some of the 856 exhibitors who had displays in 1256 booths at this year's IRE Show. Total attendance was a record 73,479.

(*Left to right*) Dr. Goldsmith, Brig. General Sarnoff, President Haggerty, and Dr. Lloyd V. Berkner, IRE Junior Past President.

Brig. General David Sarnoff, Chairman of the Board of RCA and Secretary of the IRE, 1915–1917, addressing the Golden Anniversary Banquet on free world scientific mobilization.

(*Above, left to right*) Dr. Ferdinand Hamburger, Jr., Vice Chairman of the IRE Convention; Dr. Thomas F. Jones, Jr., Spokesman for the newly elected Fellows and IRE Editor; and Dr. G. W. Bailey, Convention Chairman and IRE Executive Secretary.



Award winners: (*Left to right*) Dr. W. Culshaw, Harry Diamond Award; Dr. G. A. Morton, Vladimir K. Zworykin Award; Prof. V. H. Rumsey, Morris N. Liebmann Award; Dr. M. Chodorow and Dr. T. Wessel-Berg, W. R. G. Baker Award.

President Haggerty presenting the 1962 IRE Medal of Honor to Sir Edward Appleton, Principal and Vice Chancellor of the University of Edinburgh.

Special symposium on the proposed consolidation of IRE and AIEE. *Back row:* Joint IRE-AIEE Committee for Consolidation Consideration. *Front row:* Members of the two-man study groups of the Joint IRE-AIEE Committee.

A Tribute

A high point of the Golden Anniversary Banquet was a testimonial, bearing the signatures of every former IRE President, to IRE Founder Alfred N. Goldsmith. (*Left*) President Haggerty presenting the scroll to Dr. Goldsmith. (*See page opposite.*)

(*Below*) Dr. Goldsmith receiving a standing ovation from the banquet audience of 1400. (*On the right:* Brig. General David Sarnoff, principal speaker and Donald G. Fink, toastmaster.)

As The Institute of Radio Engineers completes its fiftieth year of service to the profession, we who have been privileged to preside over its fortunes during this half-century span do hereby pay special

Tribute to

Alfred Norton Goldsmith

who, as Co-Founder of the IRE; as Editor of the Proceedings of the IRE at its inception and for a period of forty-one years thereafter; as Editor Emeritus; as Anniversary Editor; as President for one year; as Secretary for ten; and as a Director of the IRE throughout its full and fruitful fifty-year history, has given our profession a monumental and lasting contribution and has achieved an unparalleled record of sustained, dedicated, and devoted service to the organization he fathered and to the journal he fostered.

As a token of our lasting esteem and affection for one who has thus so ably served with each and every one of us during our terms of office, we, the Presidents of the IRE, speaking for those departed as well as for those present, offer this inscribed testimonial as a remembrance of the Golden Anniversary Banquet of IRE.

Presented at the IRE Golden Anniversary Banquet
Waldorf-Astoria, New York, N. Y., March 29, 1962

Current IRE Statistics

(As of April 30, 1962)

Membership—100,075
Sections*—111
Subsections*—35
Professional Groups*—29
Professional Group Chapters—299
Student Branches†—229

* See May, 1962, for a list.
† See this issue for a list.

Calendar of Coming Events and Author's Deadlines*

1962

June 18–19: Chicago Spring Conf. on Broadcast and Television Receivers, O'Hare Inn, Chicago, Ill.

June 25–27: 6th Nat'l. Conf. on Product Engrg. and Production, Los Angeles, Calif.

June 25–27: 6th Nat'l. Convention on Military Electronics, Shoreham Hotel, Washington, D. C.

June 25–30: Symp. on Electromagnetic Theory and Antennas, Tech. Univ. of Denmark, Copenhagen.

June 27–29: Joint Automatic Control Conf., New York Univ., New York, N. Y.

June 27–28: 9th Annual Symp. on Computers and Data Processings, Elkhorn Lodges, Estes Park, Colo.

June 28–29: 4th Nat'l. Symp. on Radio Frequency Interference, Town House Hotel, San Francisco, Calif.

July 17–18: Data Acquisition and Processing in Medicine and Biology, Whipple Aud., Strong Mem. Hosp., Rochester, N. Y.

Aug. 14–16: Internat'l. Conf. on Precision Electromagnetic Measurements (former title: Conf. on Standards and Electronic Measurements), Nat'l. Bur. Standards, Boulder, Colo.

Aug. 21–24: WESCON (Western Electronics Show and Conf.) Statler Hilton and Sports Arena, Los Angeles, Calif.

Aug. 29–Sept. 1: 2nd Internat'l. Conf. on Information Processing, Munich, Germany.

Sept. 3–7: Internat'l. Symp. on Information Theory, Brussels, Belgium.

Sept. 3–7: Nat'l. Advanced Technology, Management Conf., Worlds Fair Grounds, Opera House, Seattle, Wash.

Sept. 3–7: 4th Internat'l. Congress on Microwave Tubes, Kurhaus Hotel, Scheveningen, Netherlands.

Sept. 4–7: ACM Natl. Conf., Hotel Syracuse, Syracuse, N. Y.

Sept. 13–14: 10th Annual Engineering Management Conf., Hotel Roosevelt, New Orleans, La.

* DL = Deadline for submitting abstracts.

(*Continued on page 18A*)

EIA Medal of Honor Awarded To President of RCA

Dr. Elmer W. Engstrom, President of the Radio Corporation of America was recently named by the Electronic Industries Association Board of Directors to receive the association's highest award, the EIA Medal of Honor. The medal is given for "distinguished service contributing to the advancement of the electronics industry."

Dr. Engstrom, who holds an honorary Doctor of Science degree from New York University, began work in electronics research after graduating with a Bachelor of Science degree in electrical engineering from the University in Minnesota in 1923.

He joined RCA in 1930 and worked on sound motion picture and broadcast receiver development until he began organization of the industry's first research department in the fields of apparatus and systems.

In the early 1930's, Dr. Engstrom participated in the evaluation of experimental television. He and his associates later conducted research on color TV. He was a member of the National Television Systems Committee and also served on the committee which developed technical signal specifications for color TV, which were adopted by the Federal Communications Commission in 1953.

In 1942 Dr. Engstrom became Director of General Research. He was elected Executive Vice President for Research and Engineering in 1954 and became President of RCA in 1961.

Dr. Engstrom received the Silver Plaquette of the Royal Swedish Academy of Engineering Sciences, the University of Minnesota Outstanding Achievement Award for TV research pioneering, the Radio Fall Meeting Award of the Electronics Industries Association and the Institute of Radio Engineers, the Progress Medal of the Society of Motion Picture and Television Engineers, the John Ericsson Medal of the American Society of Swedish Engineers, the rank of Commander in the Order of Merit of the Italian Republic, and the Medal for the Advancement of Research from the American Society of Metals. For several years he was Chairman of the Research and Engineering Advisory Panel on Electronics in the Office of the Secretary of Defense.

Information Theory Symposium To be Held in Brussels

The International Symposium on Information Theory will be held at the Free University of Brussels, Belgium, Sept. 3–7, 1962. The fee is fixed at $10.00. Sponsors for the symposium are the PGIT, Benelux Section and Belgian Societies.

The Organization Committee does not take any responsibility with regard to the reservation of hotel rooms; those who desire can use the help of the Agency Wagons Lits/Cook or Dean and Dawson; this agency can also make your travel arrangements. At the Cite Universitaire one can hire an individual room or take one together with another congressist.

Papers will be printed beforehand in a special issue of the IRE Transactions. For nonmembers the cost will be $5.00. In case airmail delivery is desired the extra postage will have to be paid. The issue will be printed in Europe.

It is expected that the program will contain ten sessions of four papers. There will be two sessions on each of the following topics: General Theoretical Problems, Coding, Applications to Communication Channels, Adaptive Systems and Pattern Recognition, and Human Information Processing.

For further information write to: M. Selleslags, Secretary International Symposium Information Theory, University of Brussels, Lab. d'Electricité Générale, Avenue Franklin Delano Roosevelt 50, Brussels, Belgium.

Call for Papers Electron Devices Meeting

The annual technical meeting of the Professional Group on Electron Devices will be held at the Sheraton-Park Hotel, Washington, D. C., Oct. 25–27. Because of the difficulties in scheduling meetings in Washington, D. C., the meeting will start with afternoon sessions on Thursday, Oct. 25 and end with morning sessions on Saturday, Oct. 27.

Submission of titles of papers for presentation at the meeting is requested at this time. For your convenience, a reply postal card is enclosed, to be returned no later than June 1. Indication of a possible paper to be submitted will not place the author under any obligation, but will be helpful to the committee in planning the technical program.

An informative abstract of approximately 200 words will be required for each paper to be considered for presentation at the meeting. Final deadline for acceptance of abstracts is Aug. 1, but earlier submission is requested, if possible. Abstracts, including an original and four copies, should be sent to the following address: J. Earl Thomas, Jr., IBM Components Lab., Bldg 701, Dept. 677, Poughkeepsie, N. Y.

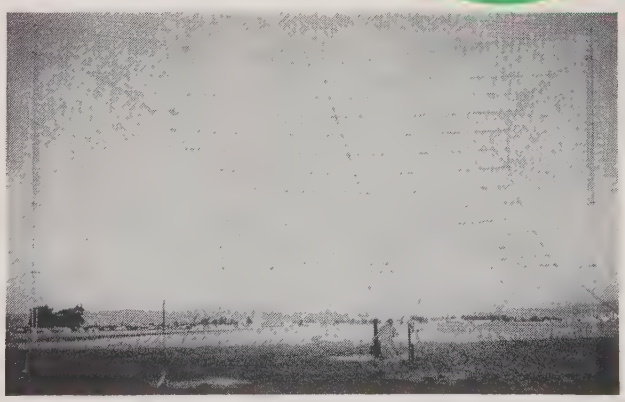
Papers to be presented at this meeting should deal with material of an applied or development nature in the broad field of electron devices. Consistent with the divisional structure of the Professional Group on Electron Devices, papers are invited in the fields of integrated electronic devices and energy sources, in addition to the fields of solid state devices and electron tubes. This meeting is intended not to overlap with the Research Conferences, which comprise papers dealing with new ideas and concepts. Papers for this meeting should be concerned primarily with the device itself or important new device technology, rather than with its application or circuitry, except insofar as circuitry is built into the device itself.

How to save acres and acres on a crowded antenna farm

For short-haul, point-to-point, h-f communications, this Granger Associates broad-band log-periodic antenna, Model 747-2.5/30, can be installed on a 3½ acre rectangle, and actually covers about 2 acres. It replaces at least two and perhaps three rhombic antennas, each requiring from 7 to 14 acres. It offers a 10.2-db gain at a frequency-independent vertical take-off angle of 45° over the 2.5—30 Mc range. VSWR is low (2:1) and efficiency is greater than 90%. It needs no ground screen, and is not seriously affected by a poorly conducting ground. For optimum sector coverage at varying distances, a special version provides take-off angle inversely variable with frequency. These antennas are now in production and in service in the U.S. and abroad. Unless you are in the market for real estate, you will want details on this and other broad-band log-periodics (plus other h-f communications systems components) from the nation's fastest-growing supplier of h-f antenna systems.

Granger Associates

Opportunities for qualified engineers: contact Jerry Franks, personnel mgr.



Model 747-2.5/30 log periodic h-f antenna

Granger Associates / 974 Commercial Street, Palo Alto, California *DAvenport 1-4175 (area code 415)*

Calendar of Coming Events and Author's Deadlines*

(Continued from page 16A)

Sept. 13–14: Natl'l. Symp. on Engineering Writing and Speech, Mayflower Hotel, Washington, D. C.
Sept. 19–20: 11th Annual Industrial Electronics Symp., Hotel Sheraton, Chicago, Ill.
Sept. 28–29: 12th Annual Broadcast Symp., Willard Hotel, Washington, D. C. (DL*: July 15, 1962.)
Oct. 1–3: 8th Nat'l. Communications Symp., Hotel Utica, Utica, N. Y.
Oct. 2–4: Nat'l. Symp. on Space Elec. and Telemetry, Fontainebleau Hotel, Miami Beach, Fla.
Oct. 7–12: AIEE 1962 Fall General Meeting—3rd Ann. Symp. on Switching, Circuit Theory and Logical Design, Chicago, Ill.
Oct. 8–10: Nat'l. Elec. Conf., McCormick Pl., Chicago, Ill.
Oct. 15–17: URSI-IRE Fall Meeting, Ottawa, Canada.
Oct. 15–18: Symp. on Space Phenomena and Measurement, Statler-Hilton, Detroit, Mich.
Oct. 22–24: ECCANE (East Coast Conf. on Aerospace and Navigational Elec.) Emerson Hotel, Baltimore, Md. (DL*: June 15, 1962.)
Oct. 25–27: Electron Devices Meeting, Sheraton Park Hotel, Wash., D. C.
Oct. 30–31: Conf. on Engrg. Techniques in Missile and Spaceborne Computers, Disneyland Hotel, Anaheim, Calif.
Nov. 1–2: 6th Nat'l. Conf. on Product Engr. and Production, Jack Tar Hotel, San Francisco, Calif.
Nov. 4–7: 15th Annual Conf. on Elec. Tech. in Medicine and Biology, Conrad Hilton Hotel, Chicago, Ill.
Nov. 5–7: NEREM (Northeast Res. and Engr. Meeting, Commonwealth Armory, Somerset Hotel, Boston, Mass.
Nov. 12–14: Radio Fall Meeting, King Edward Hotel, Toronto, Ont., Canada.
Nov. 12–15: 8th Annual Conf. on Magnetism and Magnetic Mat., Penn-Sheraton, Pittsburgh, Pa.
Nov. 16–17: Communications Symposium, Queen Eliz. Hotel, Montreal, P.Q., Canada.
Nov. 19–20: MAECON (Mid-America Electronics Conf.), Continental Hotel, Kansas City, Mo.
Nov. 28–30: 1962 Ultrasonics Symp., New York City. (DL*: August 13, 1962, for 200-word abstracts, R. N. Thurston, Bell Telephone Labs., Murray Hill, N. J.
Dec. 4–6: FJCC (Fall Joint Computer Conf.), Sheraton Hotel, Philadelphia, Pa. (DL*: June 30, 1962, for 35-word abstract, 500-word summary and completed draft of paper.)
Dec. 6–7: 13th Nat'l. Conf. on Vehicular Communications, Mayfair Hotel, Los Angeles, Calif.

1963

Jan. 22–24: 9th Nat'l. Symp. on Reliability and Quality Control, Sheraton Palace Hotel, San Francisco, Calif.

* DL = Deadline for submitting abstracts.

Quality Control Conference Set for October

The 17th Midwest Quality Control Conference will be held at the Denver Hilton Hotel, Denver, Colo., Oct. 26 and 27, 1962.

For further information write: American Society for Quality Control, P.O. Box 396, Denver, Colo.

Eminent Memberships Awarded by Eta Kappa Nu

Dr. Jerome Wiesner, Dr. Ernest Weber, and Dr. Lloyd Berkner received, after their election by Eta Kappa Nu, Honorary Electrical Engineering Society, the award of Eminent Membership of the society. The recipients are electrical engineering graduates. The award is given for meritorious contributions which help to raise the stature of the electrical engineering profession.

Dr. Wiesner, a graduate of the University of Michigan, is on leave from the Massachusetts Institute of Technology as President Kennedy's Special Assistant for Science and Technology. Dr. Weber received his diploma and Doctor of Science degree in electrical machinery at the Vienna Technische Hochschule and is now President of Brooklyn Polytechnic Institute. Dr. Berkner is a graduate of the University of Minnesota and is now President of the graduate Research Center of the Midwest.

Spaceborne Computer Engineering Conference Call for Papers

The IRE Professional Group on Electronic Computers is sponsoring a national conference on engineering technology in missile and spaceborne computers, at the Disneyland Hotel, Anaheim, Calif., Oct. 30 and 31, 1962. Papers will be on all engineering aspects of computers and digital information processing systems which are an integral part of the airborne equipment for missile and space systems. Primary emphasis for the conference will be on working equipment and techniques, but papers describing significant new approaches and future trends are also solicited. The program will include invited and contributed papers. The Conference Proceedings, with reprints of all conference papers, will be available for distribution at registration.

Authors should submit four copies of a thousand-word summary by June 15, 1962. These summaries should accurately describe the author's work in order to assist the Program Committee in selecting papers of greatest merit. Final choice of papers will be completed by July 15, and authors will be notified immediately thereafter. Final copies of the papers will be required by September 28, 1962 to allow time for printing of the Conference Proceedings. The necessary company and government clearances should be obtained before submission of summaries. All summaries should be sent by June 15 to: Dr. R. A. Kudlich, Chairman, Program Committee, AC Spark Plug Div., General Motors Corp., 950 North Sepulveda Blvd., El Segundo, Calif.

Call for Papers IRE Communications Symposium

The Second Canadian IRE Symposium on Communications will be held at the Queen Elizabeth Hotel, Montreal, Quebec, Nov. 16 and 17, 1962.

Technical papers will be accepted on any phase of the communications theme. Some acceptable topics are: 1) Low Frequency Communications Systems, 2) Broadcast Communications Systems, 3) Wire Communications, 4) Telephone Systems, 6) Scatter, 7) Lunar and Space Relays, 8) Telex, 9) Microwave Relays, 10) Telemetry, 11) Military Equipment, and 12) Interplanetary Proposals.

Original papers not previously presented are preferred, but not mandatory. Presentations should be limited from twenty to twenty-five minutes.

A 350-word summary should be submitted by June 1, 1962, together with the subject title and a short biographical note for consideration and selection by the Technical Program Committee.

The authors of accepted papers will be advised by July 1, at which time they will be requested to forward a complete transcript of their paper by Sept. 1, 1962. This deadline must be met if authors desire their paper to be published in the Proceedings of the Symposium.

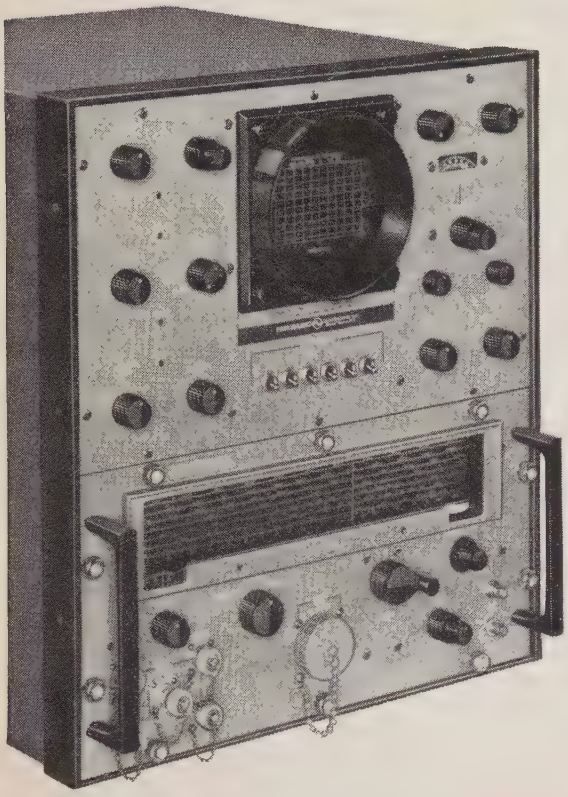
Authors of original papers who desire their papers to be forwarded to the IRE Editorial Department for consideration regarding publication in the PROCEEDINGS or TRANSACTIONS, should so indicate.

The 350-word summaries and biographical notes should be forwarded in triplicate to: Allan B. Oxley, P.Eng., Chairman Technical Program, Canadian IRE Symposium on Communications, Box 802, Station B, Montreal, Quebec.

Information Retrieval Institute Announced

The University of Minnesota, through its Library School and its Center for Continuation Study, announces an Institute on Information Retrieval, to be held Sept. 19–22, 1962. The Institute is under the direction of Dr. W. Simonton, Associate Professor, Library School, University of Minnesota. The aim of the Institute will be to present a concise picture of the present status of information retrieval, with consideration of current devices and techniques, their relation to traditional library and indexing procedures, and probable lines of future development. Papers to be presented will discuss the theoretical and practical considerations involved in the choice of efficient and effective methods for the organization of personal, library and technical information center files. Exhibits and demonstrations of "non-conventional" methods will concentrate on the problems raised by the increasing demands of specialization and interdisciplinary research in scholarly disciplines. The registration fee is $15.00. For further information write: Director, Center for Continuation Study, University of Minnesota, Minneapolis 14, Minn.

Now from Panoramic...a low-cost high performance spectrum analyzer 10mc to 43kmc with all these features:



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- **Selectivity adjustable 1-80 kc.**
- **Calibrated dispersion marker with modulation provision to measure narrow band dispersions accurately.**
- **Bright, easily read 5″ CRT display with calibrated linear, 40 db log and power amplitude scales.**
- **Single knob tuning control with illuminated slide rule scale, accurate within 1%.**
- **Crystal controlled ± 0.01% markers** (OPTIONAL) **check signal frequency calibrations over entire SPA-10 range.**
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The low cost Model SPA-10 provides sensitive broadband spectrum analysis up through Ka band in a single compact unit. Wide dispersion range to 80 mc, internal calibration and self-checking facilities, and adjustable I-F filter bandwidth for optimized selectivity, are just a few of the characteristics which recommend this carefully designed and packaged analyzer. Non-professional lab and production personnel readily master the easy-to-use SPA-10. Tuning is accomplished with a single low-backlash control which is calibrated within 1% on an illuminated slide rule scale. Excellent shielding permits accurate analysis close to high-power signal sources.

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Selectivity Adjustable I-F bandwidth, 1kc to 80kc.
Input Attenuators 100 db range for signals up to 12.1kmc. (Ext. waveguide attenuators available for 12-43kmc range.)
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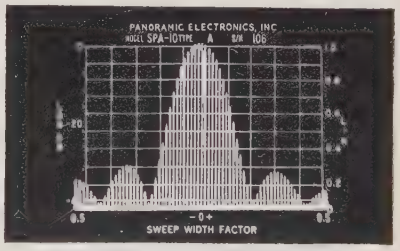
Dimensions Cabinet, 20″h x 17⅜″w x 19½″d. (For 19″ width rack mounting, specify the SPA-10/R with slide tray)

FREQUENCY	SENSITIVITY*
10 – 640 mc	– 95 to – 105 dbm
0.56 – 1.4 kmc	– 87 to – 97 dbm
1.0 – 2.24 kmc	– 79 to – 89 dbm
2.0 – 3.04 kmc	– 71 to – 81 dbm
2.9 – 6.0 kmc	– 90 to – 100 dbm
6.0 – 12.2 kmc	– 80 to – 95 dbm
12.1 – 24.4 kmc	– 70 to – 85 dbm
21.3 – 43.0 kmc	– 40 dbm nominal

*2:1 deflection ratio—CW signal: noise; 50 ohm input



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Ultrasonics Symposium Call for Papers

The 1962 Ultrasonics Symposium will be held at Columbia University, New York, N. Y., Nov. 28–30, 1962. It is sponsored by the IRE Professional Group on Ultrasonics Engineering. Contributed papers are sought in any of the various specialties of ultrasonics. At this meeting particular emphasis will be given to microwave ultrasonics and a program of invited papers has been planned to give comprehensive coverage of this field. Three copies of a 200-word abstract should be submitted prior to Aug. 13, 1962, to: R. N. Thurston, Technical Program Chairman, Bell Telephone Labs., Murray Hill, N. J.

Call for Papers Space Electronics And Telemetry Symposium

The 1962 Symposium on Space Electronics and Telemetry will be held at the Fontainebleau Hotel, Miami Beach, Fla., Oct. 2–4, 1962. Dr. A. Rudolf, Assistant Director of Systems Engineering, Office of Manned Space Flight, NASA Headquarters, is Chairman for this symposium, which is sponsored by the IRE Professional Group on Space Electronics and Telemetry.

Papers presenting original work are invited on the subject of space electronics and telemetry which will be discussed within eight unclassified sessions dealing with the following special fields: A) Telemetry, as applied to—1) Civilian and Military Projects, 2) Missiles and Space Vehicles, 3) Space Crafts and Satellites, 4) System Performance Analysis and Reliability; B) Space Electronics—1) Communication Systems, 2) Tracking, 3) Sub Systems, 4) Components.

In addition, it is planned to conduct a classified session where authorities of government agencies will present the role of electronics and telemetry with respect to the National Space Program as of fall 1962. A field trip to the Atlantic Missile Range, Cocoa Beach, Fla., and a technical exhibition of the space electronic and telemetry industry is included in the symposium's program.

The schedule for papers calls for: 1) Submission of author, title, and summary of about 1,000 words, not later than April 20, 1962. 2) Final papers not later than August 15, 1962.

Tentative selection of papers will be based on the critical review of the summary. It is recommended to clearly show the significance of the results obtained as related to the state of the art. Final selection of the papers will be made after review of the complete paper. Cash prizes of $100.00 each will be awarded to the authors of the five best papers.

Please, address correspondence with regard to the papers to: Dr. Joachim Muehlner, Lockheed Aircraft Corp., Missiles and Space Div., Bldg. 204, Plant 2, P. O. Box 504, Sunnyvale, Calif.

Correspondence with respect to the program should be directed to: Otto A. Hoberg, Program Chairman, Marshall Space Flight Center, M-ASTR-I, Bldg. 4487-B, Huntsville, Ala.

1962 PGMTT Microwave Prize Awarded to Dr. Matthaei

Dr. George L. Matthaei of Stanford Research Institute received this year's Microwave Prize at the 1962 National Symposium of the IRE's Professional Group on Microwave Theory and Techniques.

The Microwave Prize is awarded annually by the PGMTT, and its purpose is to recognize significant contributions to the fields of this organization as published in the Transactions on Microwave Theory and Techniques, the Proceedings of the IRE, or the sections of the IRE International Convention and WESCON Records containing papers sponsored by the PGMTT. The Microwave Prize consists of a certificate, a cash sum of $100.00, and a feature publication in the Transactions on Microwave Theory and Techniques.

The 1962 award is for Dr. Matthaei's paper "A Study of the Optimum Design of Wide-Band Parametric Amplifiers and Up-Converters," which appeared in the January, 1961 issue of the Transactions on Microwave Theory and Techniques.

Dr. Matthaei was his own runner-up in the Microwave Prize this year with another paper, "Design of Wide-Band (and Narrow-Band) Band-Pass Microwave Filters on the Insertion Loss Basis," which appeared in the November, 1960 issue of the Transactions on Microwave Theory and Techniques.

Congress on Electronics Scheduled for June

The Ninth International Congress on Electronics, promoted and organized by the Ministry of Posts and Telecommunications, the Institute of P.T., and the Ugo Bordoni Foundation, will be held at the Palazzo dei Congressi, Rome, Italy, June 18–23, 1962. Professors, researchers, and specialists from all over the world will participate. The topics of the congress will be: 1) Electronics in Medicine and in Biology, 2) Automation in Industry, and 3) Communications.

The third section will be devoted particularly to the following aspects of communications: 1) Telecommunications by means of artificial satellites, 2) Low noise amplifiers, and 3) The Laser and its possibilities.

A general survey of the present and future applications of electronics will conclude the Congress.

Professional Group News

At its meeting on April 24, 1962 the IRE Executive Committee approved the following new chapters: Joint PG on **Antennas and Propagation, Electron Devices** and **Microwave Theory and Techniques**—Detroit Chapter; Joint PG on **Antennas and Propagation** and **Microwave Theory and Techniques**—Montreal Chapter; PG on **Circuit Theory** and **Information Theory** to be combined to form one Joint Chapter—Syracuse Chapter; PG on **Circuit Theory**—Cleveland Chapter; PG on **Communications Systems**—Dallas Chapter; PG on **Instrumentation**—Boston Chapter.

PGBTR Call for Papers For 1962 Radio Fall Meeting

The Professional Group on Broadcast and Television Receivers is sponsoring two sessions at the 1962 Radio Fall Meeting to be held at the King Edward Hotel, Toronto, Can., Nov. 12–14.

A 100-word summary of proposed papers is to be sent to: William O. Swinyard, Hazeltine Research Inc., 5445 West Diversey, Chicago 39, Ill., by July 2, 1962. Papers should represent significant advances in radio and television receivers.

Joint Computer Conference Proceedings Offered

Copies of Conference Proceedings for the 1962 Spring Joint Computer Conference are available from: The National Press, 850 Hansen Way, Palo Alto, Calif.

The cost is $6.00 per copy for AFIPS society members and non-members. Postage will be paid on orders accompanied with a check.

The National Press will handle requests until Spring, 1964 provided copies of the initial printing of the Proceedings are available.

Obituary

Dr. Howard T. Engstrom (SM'53–F'59), research scientist and former Deputy Director of the National Security Agency, died March 9, 1962 at Carney Hospital, Boston, Mass., after an illness of several months.

Dr. Engstrom was a Vice President and Director of Marketing of Scientific and Military Systems for the Remington Rand Univac division of Sperry Rand Corporation.

He was one of the creators of the Univac scientific computer and a founder of Engineering Research Associates, St. Paul, Minn. He became Vice President of Remington Rand in 1952. He resigned in 1956 to join the National Security Agency, but returned in 1958.

When Dr. Engstrom left the National Security Agency, Neil H. McElroy, then Secretary of Defense, cited him for "exceptional meritorious civilian service."

Dr. Engstrom was born in Boston, Mass., on April 23, 1902. He received a Bachelor of Chemical Engineering degree from Northeastern University in 1922, a Master's degree from the University of Maine in 1925, and a Doctorate of Philosophy degree from Yale University in 1929.

He joined the Yale faculty in 1926 as an instructor and was an Associate Professor in 1941 when he resigned to enter military service.

A Fellow of Davenport College, Dr. Engstrom received the Distinguished Service Medal, the Order of the British Empire, the Naval Reserve Medal, and a Presidential Unit citation for his service during the war as a Captain in the United States Naval Reserve.

Dr. Engstrom was a National Research Fellow at the California Institute of Technology in 1930 and an International Research Fellow at Gottingen, Germany, in 1931.

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Sixth National Convention on Military Electronics (MIL-E-CON 1962)

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Special sessions on "The Electronics Industry and Arms Control" and on "The Role of the Non-Profit Research and Development Organizations in National Defense Activities" will highlight the Sixth National Convention on Military Electronics which will be held at the Shoreham Hotel, Washington, D. C., June 25–27, 1962.

This annual meeting, known as MIL-E-CON, is sponsored by the Professional Group on Military Electronics. Ralph I. Cole is Convention President for MIL-E-CON 1962.

Technical papers on various phases of military electronics will be presented during the fifteen technical sessions which begin Monday afternoon. Two sessions will feature invited papers.

The 1962 Conference Proceedings will be distributed free to all registrants at the Convention.

The tentative technical program follows:

Monday Morning, June 25

Moderator: *D. E. Bell, Director, Bureau of the Budget.*

Panel: *H. Davis, Deputy Assistant Secretary of the Air Force, Research and Development; A. Yarmolinsky, Special Assistant to the Secretary of Defense; Dr. I. A. Getting, President, Aerospace Corp.; E. V. Huggins, President, National Security Industrial Associations; and Major General J. McCormack, USAF (Ret.), Vice President, MIT.*

Monday Afternoon

Sessions 1P1—Frontiers in Electronics (Invited Papers)

Moderator: *Dr. A. Shostak, Office of Naval Research.*

Session 1P2—Reliability I

Moderator: *Dr. P. H. Zorger, Martin Marietta Corp.*

"Reliability Program," *J. C. Culbertson, Western Electric, Winston Salem, N. C.*

"Redundancy and Reliability," *W. E. Hansalik, Autonetics, Downey, Calif.*

"Methodology for Performance Degradation Analysis" *S. Weisman and B. Tiger, RCA, Camden, N. J.*

"Application of Sequential Sampling Techniques to Monte Carlo Methods of Reliability Analysis," *C. H. Beatty and B. C. Spradlin, Battelle Memorial Institute, Columbus, Ohio.*

"Qualification Strength Required of Electronic Circuits," *S. A. Francis, Sippican Corp., Marion, Mass.*

"Reliability—A Product of ACREE-3 Testing," *R. L. Vander Homm and R. L. Pollock, Collins Radio Co., Cedar Rapids, Iowa.*

"Unit Redundancy Scheme for Higher Control System Reliability," *A. S. Escobosa, Autonetics, Downey, Calif.* (Standby paper)

Session 1P3—Systems I

Moderator: *A. G. Wimer, Air Force Systems Command.*

"A Manually Controlled Stellar Acquisition and Tracking System for Astronomical Research on the X-15 Research Vehicle," *R. D. Seinfeld, Astronautics Corp. of America, Milwaukee, Wis.*

"Optimizing Advanced Radar Systems: Considerations of Performance, Cost and Complexity," *Mrs. S. S. Jamison, Arthur D. Little, Inc., Cambridge, Mass.*

"The Command and Control Dilemma," *B. Baldridge, General Electric, Utica, N. Y.*

"SPAN, A Practical Coherent System Analysis Method," *J. C. O'Brien, Northronics Division of Northrop Corp., Anaheim, Calif.*

"Functional and Environmental Requirements for Military Uses of Man in Space," *I. Katz, General Electric Co., Ithaca, N. Y.*

"Balistic Missile Defense Systems in an Arms Control Environment," *R. N. Hazelwood and Mrs. S. S. Jamison, Arthur D. Little, Inc., Cambridge, Mass.* (Standby paper)

Session 2A1—Vistas in the Informational Sciences (Invited Papers)

Moderator: *Dr. M. C. Yovits, Office of Naval Research.*

Tuesday Morning, June 26

Session 2A2—Computer and Trainer Applications

Moderator: *L. D. Shergalis, Electronics Magazine.*

"Analog Computer Simulation of Synthetic Spectrum Radar System," *H. S. Olson, Westinghouse Electric Corp., Baltimore, Md.*

"A Control Computer for Missile Test and Launch Systems," *J. H. Lane, L. O. Johnson, and W. R. Loutensock, Douglas Aircraft Co., Santa Monica, Calif.*

"A Precision Digital-Analog Control System for a Tracking Telescope," *C. Cantor and P. S. P. Hui, NASA, Goddard Space Flight Center, Greenbelt, Md.*

"A Real Time Digital Computer for Radar Control and Data Processing," *R. F. Day and C. A. Hobbs, RCA, Moorestown, N. J.*

"Trainer Concepts for Missile Systems," *H. Chaskin, U. S. Naval Training Device Center, Port Washington, N. Y.*

"ADD—An Ultra-Reliable Computer for Missile and Space Applications," *R. P. Blixt, D. C. Morse, and B. J. Jansen, Remington Rand Univac, St. Paul, Minn.* (Standby paper)

Sessions 2A3—Systems II

Moderator: Dr. R. A. Weiss, Office Chief of Research and Development.

"System Design of Orbital Tracking Instrumentation," *Dr. S. Shucker and R. Lieber, RCA, Moorestown, N. J.*

"An Approach to Automatic Photointerpretation," *Dr. A. Rosenfeld, Budd Electronics, Long Island City, N. Y.*

"Automatic Checkout of the Agena Satellite Utilizing the AN-GJQ-9 Programmer-Comparator," *D. A. McClary and D. M. Hill, Lockheed Aircraft Corp., Van Nuys, Calif.*

"The New UHF Telementry Bands: System Considerations and Hardware Solutions," *H. D. Dickstein, Cubic Corp., San Diego, Calif.*

"Space Rendezvous Interferometer Antenna," *P. S. Hacker and M. S. Wheeler, Westinghouse Electric Corp., Baltimore, Md.*

"Zero-Gravity Parabola Techniques," *R. Weiss, Lear, Wright-Patterson AFB, Ohio.* (Standby paper)

Tuesday Afternoon

Session 2P1—Techniques I

Moderator: *Dr. H. A. Zahl, USASRDL.*

"Tunnel Diode—Coupled Transistor Circuits for High-Speed, Micro-Energy Digital Systems," *J. A. Fkiss and P. Spiegel, Philco Corp., Lansdale, Pa.*

"A Buffer Memory for Synchronous Digital Networks," *C. J. Byrne and J. V. Scattaglia, Bell Telephone Labs., Murray Hill, N. J.*

"A High-Speed Precision Instrumentation Tape Recorder," *B. A. Cola and J. Uritis, RCA, Moorestown, N. J.*

"Sensitivity Improvement for Wide-Open Receivers," *R. V. Lowman and W. J. Keane, Airborne Instruments Lab., Melville, L. I., N. Y.*

"Signal Space, Modulation and Bandwidth," *J. M. Kirshner, DOFL, Washington, D. C.*

"Modulation of Xenon Arc Lamps," *J. K. Buckley and D. R. Gerue, Raytheon Co., Santa Barbara, Calif.*

Session 2P2—Communications I

Moderator: *J. A. Krcek, Defense Communications Agency.*

"Evaluation of Tactical Communications Combat Effectiveness by Electronic Computer Simulation," *J. J. Lamb, USAEPG, Ft. Huachuca, Ariz.*

"Performance of Digital Communications System in an Arbitrary Fading Rate and Jamming Environments," *A. B. Glenn and G. Lieberman, RCA, Camden, N. J.*

"Some Performance Factors of Speech Processing Systems," *W. A. Runge, ITT Federal Laboratories, Palo Alto, Calif.*

"Some Experiments Upon the Supra-Segmental Speech Code," *W. R. Roberts, ITT Federal Laboratories, Palo Alto, Calif.*

"Coordinating Antenna Performance to Communication Circuit Requirements," *S. Perlman, U. S. Army Signal Radio Propagation Agency, Ft. Monmouth, N. J.*

"Aspect—Sensitive Spread and Multipath Delay On Off Azimuth HF Arctic Signals Largely Above the MUF," *H. S. Marsh, R. A. Swirbalus, R. J. Cormier, and B. R. Jones, AFCRL, Bedford, Mass.* (Standby paper).

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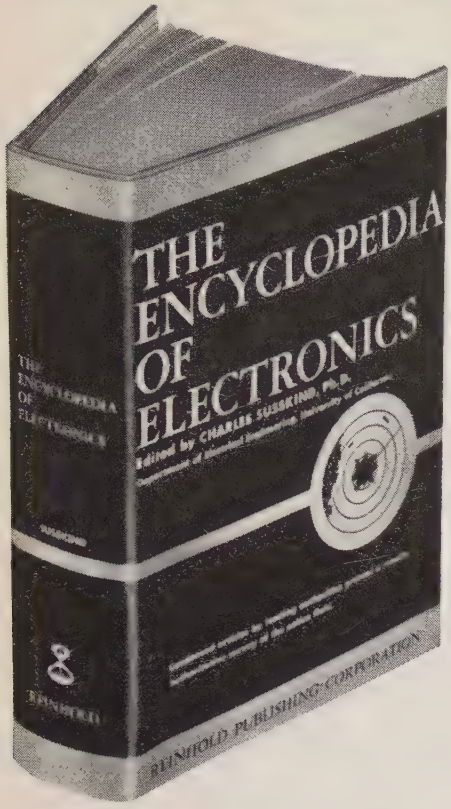

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Session 2P3—Space Electronics

Moderator: *Dr. R. O. Burns, Office of the Chief of Naval Operations.*

"Major System Tradeoffs Among Fixed, Transportable, and Mobile Stations in Satellite Communication Systems," *A. Alma and H. Hutchinson, ITT Communications Systems, Inc., Paramus, N. J.*

"Radiation Environments Inside Space Vehicles," *R. L. Daniel, Aeronutronics, Div. of Ford Motor Company, Newport Beach, Calif.*

"Kinematic Factors in Satellite Detection," *N. S. Potter, RCA, Moorestown, N. J.*

"Modulation Techniques for High Resolution Visual Data," *C. M. Barrack and L. B. Zahalka, Aircraft Armaments, Cockeysville, Md.*

"Ionic Propulsion for Space Vehicles," *J. R. Anderson and J. E. Etter, Hughes Res. Labs., Malibu, Calif.*

"Orbital Radio Monitoring," *J. A. Webb, Lockheed Aircraft, Marietta, Ga.* (Standby Paper)

Tuesday Evening

Session 2N—The Electronics Industry and Arms Control

Moderator: *Dr. H. M. O'Bryan, Bendix Corp.*

"Arms Control and National Security," *Dr. D. G. Brennan, Lincoln Labs., MIT, Lexington, Mass.*

"Weapons System Design for an Arms Control Environment," *Dr. J. P. Graven, Naval Bureau of Weapons, Washington, D. C.*

"Arms Control from the Viewpoint of Industry," *Dr. R. C. Raymond, General Electric, Santa Barbara, Calif.*

"Arms Control and the Technical Man," *Dr. F. A. Long, Arms Control and Disarmament Agency, Washington, D. C.*

Question and Discussion Panel: This will include the above speakers, *Dr. J. Phelps, Institute for Defense Analyses, Washington, D. C., and L. C. Van Atta, Hughes Research Labs., Malibu, Calif.*

Wednesday Morning, June 27

Session 3A1—Applications of Microelectronics

Moderator: *Dr. J. D. Meindl, U. S. Army Signal R & D Laboratory*

"Applications of High Density Electronic Packaging Systems," *D. S. Elders, USASRDL, Ft. Monmouth, N. J.*

"The Use of Circuit Techniques in the Solution of Microelectronics System Problems," *R. E. Warr, General Electric, Syracuse, N. Y.*

"Applications of Thin Films to Integrated Circuits," *J. R. Black, Motorola Inc., Scottsdale, Ariz.*

"A Computer Using the Semiconductor Network Approach to Integrated Circuitry," *W. J. Watson, Texas Instruments, Inc., Dallas, Tex.*

"Micrologic System Design Considerations," *R. Norman, R. Crippen, and S. Fok, Fairchild Semiconductor Corp., Palo Alto, Calif.*

"A Miniaturized Receiver Using Molecular Engineering Techniques," *H. M. Wasson, Westinghouse Electric Corp., Baltimore, Md.* (Standby Paper)

Session 3A2—Radar

Moderator: *Dr. R. C. Guthrie, U. S. Naval Research Lab.*

"The Effect of Obstacles on the Accuracy of Conical Scan Radar," *J. Callahan and L. Topper, Sperry Gyroscope Co., Great Neck, L. I., N. Y.*

"The Use of Solar Emission for the Measurement of Radar Angle Errors," *J. T. Kennedy and O. W. Rosson, Bell Telephone Labs., Whippany, N. J.*

"Target Track Correlation with a Search Memory," *E. C. Joseph and A. Kaplan, Remington Rand Univac, St. Paul, Minn.*

"Evaluation of the Effect of Random Tropospheric Propagation Phase Errors on Synthetic Array Performance," *L. A. Rondinelli and G. W. Zeoli, Hughes Aircraft Co., Culver City, Calif.*

"Detection of Targets in Side Lobe Clutter," *R. R. Campbell, Westinghouse Electric Corp., Baltimore, Md.*

"Radar Signal Processing for Space Surveillance," *N. R. Hill, RCA, Moorestown, N. J.* (Standby Paper)

Session 3A3—Reliability II

Moderator: *E. J. Nucci, Office Secretary of Defense.*

"K Factors in Quantitative Reliability," *R. H. Hollis, Bendix Corp., Mishawaka, Ind.*

"To Tell the Truth: Reliability Engineering Review," *W. W. DeVille, Philco Corp., Palo Alto, Calif.*

"A Survey of Techniques for Analysis and Prediction of Equipment Reliability," *H. E. Blanton, Raytheon, Lexington, Mass. and R. M. Jacobs, Sylvania, Waltham, Mass.*

"Graphic Solution of Reliability Logic Equations," *W. E. Marshall, Minneapolis-Honeywell, Hopkins, Minn.*

"Estimation of Component and System Failure Rates from Test Data," *R. Mirsky, RCA, Camden, N. J.*

"Relationship of Field Reliability to Reliable Chamber Test Results," *R. H. Gauger, Hazeltine Corp., Little Neck, N. Y.*

"Reliability of Welded Electronic Connections," *M. Hurowitz, Sylvania, Mountain View, Calif.* (Standby paper)

Wednesday Afternoon

Session 3P1—Techniques II

Moderator: *G. R. Kilgore, Westinghouse Electric Corp.*

"Recent Developments and Applications of RF Ferrites for Military Communications," *W. W. Malinofsky and M. Eisenberg, USASRDL, Ft. Monmouth, N. J.*

"Some Aspects of Microwave Phase Shifters Using Varactors," *A. E. Cohen, Autonetics, Downey, Calif.*

"Semiconductor and Hybrid TWT Modulators," *Earl H. Heckman, Westinghouse Electric Corp., Baltimore, Md.*

"Semiconductor Thermistors in Extreme Environments," *A. B. Kaufman, Litton Systems, Inc., Woodland Hills, Calif.*

"A High Resolution Electro-Luminescent Coordinate Panel," *P. F. Evans, C. G. Cook, and D. Reed, Kearfott Div., General Precision, Little Falls, N. J.*

"A Broadband, Dual-Mode, Spiral Monopulse Antenna," *P. Shelton, Radiation Systems, Inc., Alexandria, Va.* (Standby Paper)

Session 3P2—Communications II

Moderator: *H. Davis, Air Force.*

"Optical Radio," *D. Luck, RCA, Princeton, N. J.*

"An Accordion Communication System for Mobile Use," *J. Klapper and B. Rabinovici, RCA, New York, N. Y.*

"A New Concept for Multiplexing Communication Signals," *A. H. Ballard, Bernard Electronic Co., Washington, D. C.*

"Quasi-Passive Satellite Relay Communication System," *E. L. Gruenberg and C. M. Johnson, IBM, Rockville, Md.*

"A New Digital Matched Filter Communication Technique," *G. E. Goode, Texas Instruments, Dallas, Tex.* (Standby Paper)

Session 3P3—Guidance and Control

Moderator: *W. J. Sen, Air Force Systems Command.*

"The Skybolt Digital Data Link," *D. R. Andelin, Douglas Aircraft Co., Santa Monica, Calif.*

"ICBM Radio Midcourse Guidance," *S. W. Fordyce and W. F. Hamilton, General Electric Co., Santa Barbara, Calif.*

"The Helmet-Integrated Sight and Control System—Its Application to Helicopter Armament," *E. Shockley and H. L. Shapiro, Sperry Gyroscope Co., Great Neck, L. I., N. Y.*

"Digital-Control Camera System," *C. W. Diem, General Precision, Librascope Div., Glendale, Calif.*

"An Ultra-Low Drift All-Pneumatic Gyroscope," *G. B. Speen, ITT Federal Labs., San Fernando, Calif.* (Standby Paper)

1962 Joint Automatic Control Conference

NEW YORK UNIVERSITY, NEW YORK, N. Y., JUNE 27–29, 1962

The 1962 Joint Automatic Control Conference will be held at New York University, New York, N. Y., June 27–29. The conference will be sponsored by PGAC, AIEE, ISA, ASME, and AICHE. A special preconference registration fee of $18.00 has been set for members of each of the five participating societies; the deadline for this reduced rate is June 19. Thereafter, the fee will be $20.00. The pre-registration fee for nonmembers is $23.00, and $25.00 after the deadline.

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Wednesday Morning, June 27

Session I

Chairman: *A. S. Robinson, Kollsman Instrument Co., Elmhurst, N. Y.*

Welcome: *J. R. Ragazzini, Dean of Engineering, New York Univ.*

Introductory remarks: *A. S. Robinson, Chairman; A. J. Hornfeck, Bailey Meter Co., Cleveland, Ohio, Program Chairman; L. J. Hollander, New York Univ., Local Arrangements Chairman.*

"Report of American Automatic Control Council on Status of Control Research in United States," *J. E. Ward, MIT, Cambridge, Mass.*

"Frontiers of Integrated Automatic Control—Defense and Industrial Systems," *J. R. Moore, President, Autonetics, Div. of North American Aviation, Inc., Downey, Calif.*

"Biological Control Systems," *Dr. W. R. Ashby, Prof. of Electrical Engineering, University of Illinois, Urbana, Ill.*

Wednesday Afternoon

Session II—Optimum Control I

"Automatic Optimizing of Poorly Defined Processes, Part 1," *H. Chestnut, R. R. Duersch, and W. M. Gaines, General Electric Co., Schenectady, N. Y.*

"An Application of Functional Analysis to the Optimal Control Problem," *G. M. Kranc and P. E. Sarachik, Columbia Univ., New York, N. Y.*

"Dynamic Programming: Cumulative Errors in the Evaluation of an Optimal Control Sequence," *J. Guignabodet, IBM Research Lab., San Jose, Calif.*

"Hill Climbing Methods for the Optimization of Multi-parameter Noise Disturbed Systems," *H. J. Kushner, MIT, Lincoln Lab., Lexington, Mass.*

Session III—Nonlinear Systems I

"A Generalized Mathematical Theory for the Analysis of a Certain Class of Nonlinear Time Varying Multiple Loop Feedback Systems," *A. Y. Bilal, L. F. Kazda, Univ. of Michigan, Ann Arbor, Mich.*

"On the Application of Zubov Method for Construction of Liapunov's Functions for Nonlinear Autonomous Systems," *G. P. Szego, Purdue Univ., Lafayette, Ind.*

"Lagrange Stability of Nonlinear Feedback Systems," *Z. V. Rekasius, Purdue Univ., Lafayette, Ind.*

"A Technique for the Synthesis of Linear Non-stationary Feedback Systems—Part I: The Approximation Problem," *A. R. Stubberud.*

Session IV—Adaptive Control I

Chairman: *D. P. Eckman, Systems Center, Case Inst. of Tech., Cleveland, Ohio.*

"Multivariable Adaptive Control System," *N. N. Puri, Drexel Inst. of Tech., Philadelphia, Pa., and C. N. Weygandt, Moore School of Elec. Engr., Univ. of Penn., Philadelphia, Pa.*

"Use of a Generalized Dynamic Model with Adaptation for Optimizing Control of a Continuous Process," *J. W. Bernard and I. Lefkowitz, Case Inst. of Tech., Cleveland, Ohio.*

"An Approach to Self-Adaptive Control Based on the Use of Time Moments and a Model Reference," *M. L. Moe and G. J. Murphy, Dept. of Elec. Engr., Northwestern Univ., Evanston, Ill.*

Session V—Performance Measures I

Chairman: *H. R. Weed, Dept. of Elec. Engr., Ohio State Univ., Columbus, Ohio.*

Introductory Talk: "Problems of Systems Measurement," *J. D. Cowan, North American Aviation Co. and Dept. of Elec. Engr., Ohio State Univ., Columbus, Ohio.*

"Multiloop Control System Study of a Gas Turbine Compressor and Power Unit—Part II: Experimental Investigation," *J. R. Shull and G. S. Russell, AiResearch Mfg. Co. of Arizona, Phoenix, Ariz.*

"Application of Multiple Regression Analysis to Measurement of Time-Varying Dynamic Systems," *J. I. Elkind, D. M. Green, and E. A. Starr, Bolt Beranek & Newman, Inc., Cambridge, Mass.*

"Techniques for Identification of Linear and Linear Time-Varying Processes," *K. A. Bishop, C. M. Sliepcevich, Dept. of Chem. Engr., and T. M. Puckett, Dept. of Elec. Engr., Oklahoma Univ., Norman, Okla.*

"An Extension of the Nyquist-Barkhausen Stability Criterion to Linear, Lumped-Parameter Systems with Time-Varying Elements," *J. J. Bongiorno, Jr., Polytechnic Inst. of Brooklyn, N. Y.*

Wednesday Evening

Session VI—Performance Measurements

Chairman: *W. C. Schultz, Cornell Aeronautical Lab., Buffalo, N. Y.*

Panelists: *John Zaborszky, Washington Univ., St. Louis, Mo.; G. E. Gibson, Purdue Univ., Lafayette, Ind.; D. T. McRuer, Systems Technology, Inc., Inglewood, Calif.; F. J. Ellert, General Electric Co., Schenectady, N. Y.*

Session VII—Control Computer Availability: Its Need and Implication

Chairman: *H. R. Koen, Jr., Systems Div., Minneapolis-Honeywell Reg. Co., Pottstown, Pa.*

Panelists: *T. J. Williams, Monsanto Chemical Co., St. Louis, Mo.; Warren Gaines, General Electric Co., Phoenix, Ariz.; W. Summers, Ebasco Services, Inc., New York, N. Y.; J. V. Werme, Bailey Meter Co., Cleveland, Ohio.*

Thursday Morning, June 28

Session VIII—Process Dynamics

Chairman: *E. W. James, E. I. du Pont de Nemours, Newark, Del.*

"Dynamics of Liquid-Solid Fluidized Bed Expansion," *Liang-tseng Fan, J. A. Schmitz, and E. N. Miller, Kansas State Univ., Manhattan, Kan.*

"Frequency Response of Tubular Flow Systems," *Liang-tseng Fan and Yong-Kee Ahn, Kansas State Univ., Manhattan, Kan.*

"Transient and Steady State Size Distributions in Continuous Mixed Suspension Crystallizers," *M. A. Larson, A. D. Randolph, Dept. of Chem. Engr., Iowa State Univ., Ames, Iowa*

"Frequency and Time Domain Approaches to Limit Cycle Amplitude Dynamics," *W. E. VanderVelde, MIT, Cambridge, Mass., and A. Gelb, Dynamics Research Corp., Cambridge, Mass.*

Session IX—State Space Techniques for Control Systems I

Chairman: *John Zaborszky, Washington Univ., St. Louis, Mo.*

"Introduction to State Space Concepts," *L. A. Zadeh, Univ. of Calif., Berkeley, Calif.*

"Application of State Space Techniques to Linear Systems," *C. A. Desoer, Univ. of Calif., Berkeley, Calif.*

Session X—Optimum Control II

Chairman: *S. Chang, Dept. of Elec. Engr., New York Univ., New York, N. Y.*

"The Optimal Control of Some Attitude Control Systems for Different Performance Criteria," *I. Flugge-Lotz and H. Marbach, Stanford Univ., Calif.*

"On Some Approximation Techniques in Solving Optimization Problems in Control Systems," *Masanao Aoki, Univ. of Calif., Berkeley, Calif.*

"The Dodco Optimal Control System—A Critical Evaluation," *E. G. Rynaski, J. M. Schuler, Cornell Aeronautical Lab.*, Buffalo, N. Y.

"The Design of Optimum Controllers for Linear Processes with Energy Limitations," *B. Friedland, Melpar, Inc., Boston, Mass.*

Session XI—Nonlinear Systems II

"A New Dual-Input Describing Function and an Application to the Stability of Forced Nonlinear Systems," *J. E. Gibson and R. Sridhar, Purdue Univ., Lafayette, Ind.*

"The Frequency Responses and Jump Resonance Phenomena of Nonlinear Feedback Control Systems," *H. Hatanaka, Tohoku Univ., Sendai, Japan.*

"The Dynamic Input-Output Analysis of Limit Cycling Control Systems," *A. Gelb, Dynamics Research Corp., Cambridge, Mass.*

"A Technique for the Synthesis of Linear Non-stationary Feedback Systems—Part II: The Synthesis Problem," *A. R. Stubberud.*

Thursday Afternoon

Session XII—Process Control

Chairman: *H. T. Bates, Dept. of Chem. Engr., Kansas State Univ., Manhattan, Kan.*

"Design and Control of Feed-Effluent Exchanger-Reactor Systems," *J. M. Douglas, J. C. Orcutt, and P. W. Berthiaums, Atlantic Refining Co., Philadelphia, Pa.*

"Time Optimal Control of a Chemical Reactor," *J. E. Cotter and Y. Takahashi*, Univ. of Calif., Berkeley, Calif.

"Dynamic Optimization of a Distillation Column," *R. L. Zahradnik, D. H. Archer, and R. R. Rothfus, Westinghouse, Pittsburgh, Pa.*

Session XIII—State Space Techniques for Control Systems II

Chairman: *J. E. Gibson, Purdue Univ., Lafayette, Ind.*

"Analysis of Sampled Data Systems by State Space Techniques," *J. E. Bertram, IBM Research, San Jose, Calif.*

"Optimal Systems by State Space Techniques," *L. F. Kazda, Univ. of Michigan, Ann Arbor, Mich.*

"State Space Techniques Applied to the Design of Space Navigation System," *S. F. Schmidt, Lockheed Missile and Space Co., Sunnyvale, Calif.*

"Bibliography of State Space Techniques," *T. J. Higgins, Univ. of Wisconsin, Madison, Wis.*

Session XIV—Statistical Methods in Control

Chairman: *John Milsum, McGill Univ., Montreal, Quebec.*

"A Method of Producing Multiple Non-Correlated Random Signals from a Single Gaussian Noise Source," *P. I. Boulton, Univ.*

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"Optimal Control of Systems with Generalized Poisson Inputs," *J. J. Florentin, Elec. Engr. Dept.*, Imperial College, London, England.

"Error Probability Density for a Class of Nonlinear Control Systems with Random Step Input," *W. N. Wonham, Purdue Univ., Lafayette, Ind.*

"A Simple Iterative Procedure for the Identification of the Unknown Parameters of a Linear Time Varying Discrete System," *H. Kushner, MIT, Cambridge, Mass.*

Friday Morning, June 29

Session XV—Optimization Application

Chairman: *G. C. Newton, Jr., MIT, Dept. of Elec. Engr., Cambridge, Mass.*

"Synthesis of Feedback Controls Using Optimization Theory—An Example," *F. J. Ellert, C. W. Merriam, III, General Electric Co., Schenectady, N. Y.*

"A Self Adaptive Control System for the Saturn Booster," *R. K. Smyth, J. C. Davis, Autonetics, Downey, Calif.*

"Control Engineering Applications of V. I. Zubov's Construction Procedure for Lyapunov Functions," *S. G. Margolis and W. G. Vogt, Univ. of Pittsburgh, Pa.*

"Synthesis of a Minimum Energy Controller Subject to an Average Power Constraint," *A. E. Pearson.*

Session XVI—Discrete Adaptive Processes I

Chairman: *J. T. Tou, Northwestern Univ., Evanston, Ill.*

"Adaptation and Feedback," *J. Sklansky, RCA Labs., Princeton, N. J.*

"Self-Organizing Control Systems," *M. D. Mesarovic, Case Inst. of Tech., Cleveland, Ohio.*

"Analytic Techniques for the Study of Neural Nets," *F. Rosenblatt, Cornell Univ., Buffalo, N. Y.*

"Pattern Recognition and Adaptive Control," *B. Widrow, Stanford Univ., Calif.*

Friday Afternoon

Section XVII—Applications and Components

"Design of Some Active Compensators of Feedback Controls," *R. E. McCamey and G. J. Thaler, U. S. Naval Post Graduate School, Monterey, Calif.*

"Analysis, Design and Test of a Position Servo Utilizing a Stepper Motor," *J. C. Nicklas, Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena, Calif.*

"Closed Loop Adaptation Applied to Missile Control," *W. K. Waymeyer, Douglas Aircraft Corp., Santa Monica, Calif.*

Session XVIII—Sampled Data Systems

"A General Solution for Linear, Sampled-Data Control," *T. L. Gunckel, II, Autonetics, Downey, Calif., and G. F. Franklin, Stanford Univ., Calif.*

"On the Equivalence of Discrete Systems in Time-Optimal Control," *E. Polak, Univ. of Calif., Berkeley, Calif.*

"The Digital Adaptive Control of a Linear Process Modulated by Random Noise," *C. Pottle, University of Ill., Urbana, Ill.*

"A Perturbation Approach to an Adaptive Sampled Data Control System," *Paul Mosner, Avco Mfg. Co.*

"Stability of a Class of Discrete Control Systems Containing Nonlinear-Gain Elements," *Shinzo Kodama.*

Session XIX—Discrete Adaptive Processes II

Chairman: *L. Kanal, General Dynamics/Electronics.*

"Some Current Problems in Discrete Models of Learning," *F. Restle, Indiana Univ., Bloomington, Ind.*

"Stochastic Learning and a Quantal Model of Signal Detection, *D. A. Norman, Univ. of Penn., Philadelphia, Pa.*

"Some Current Problems in Models of Learning for a Continuum of Responses," *P. Suppes, Stanford Univ., Calif.*

"Adaptive Mechanisms in Digital 'Concept'-Processing," *M. Kochen, IBM Research Labs., Yorktown Hts., N. Y.*

Friday Evening

Session XX—Discrete Adaptive Processes

Chairman: *Jack Sklansky, RCA Labs., Princeton, N. J.*

Panelists: Authors of Papers for Sessions I and II of Discrete Adaptive Processes.

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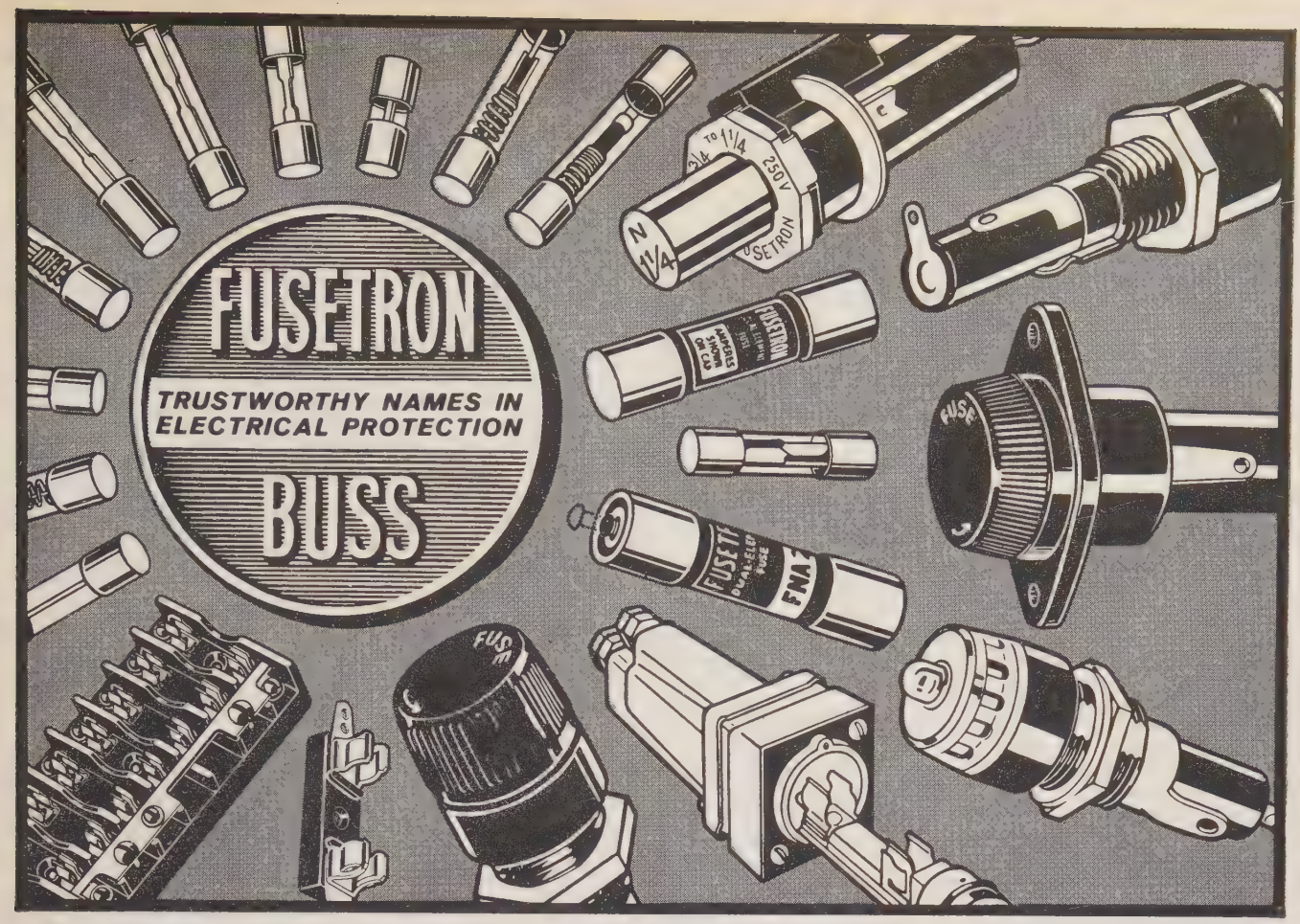

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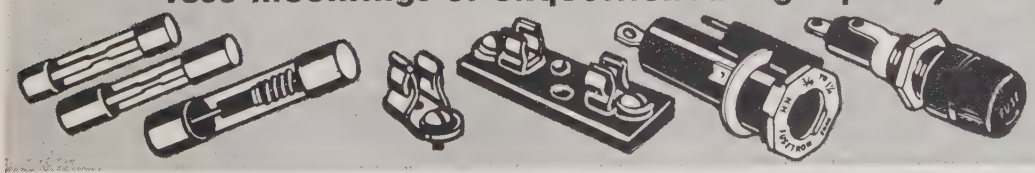

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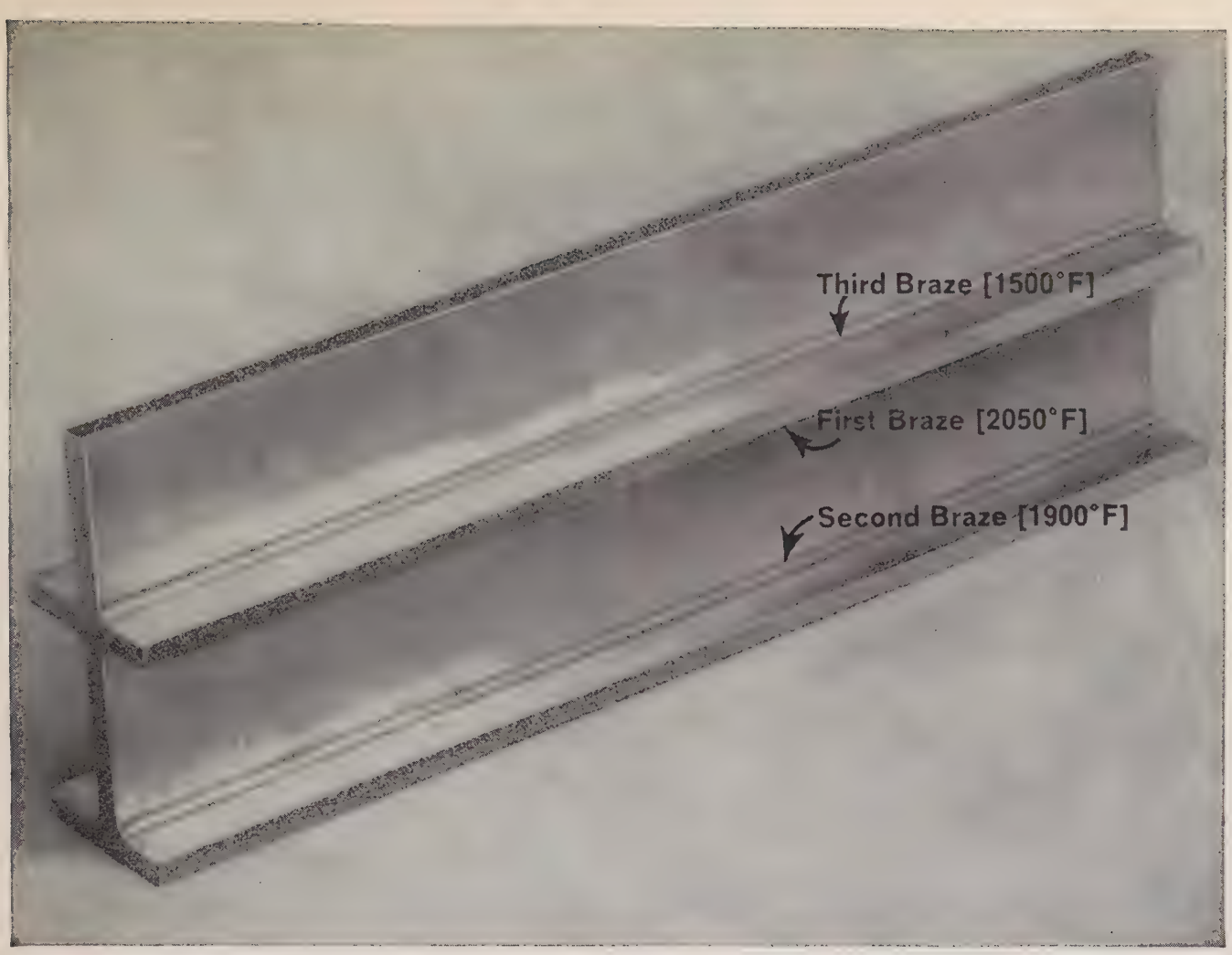

MONEL Alloy 404 . . . a new nonmagnetic alloy that can be multiple brazed in wet hydrogen

During multiple brazing operations, furnace atmospheres must contain enough water vapor to prevent the brazing alloy from wetting the fixtures. Yet the parts to be brazed must remain wettable to insure free flow, even after two or three trips through the furnace.

MONEL* Alloy 404 is a nickel-copper composition in which residual elements are held to low levels, to provide a clean, wettable surface to the brazing alloy even after continued exposure to wet hydrogen. And it retains the basic properties of MONEL Alloy 400...low vapor pressure, strength, ductility, corrosion resistance.

Brazed three times in wet hydrogen —The test assembly above illustrates the excellent brazing properties of MONEL Alloy 404. It was built up in three slow passes through the furnace using hydrogen with a dew point of +70°F. On the third pass, the brazing alloy still flowed the full length of the joint.

The low magnetic permeability of MONEL Alloy 404 is not significantly affected by processing and fabrication, making it particularly suited for electronic parts. In any commercial form, size, or temper the permeability will not exceed a value of 1.1 at 27°F when measured using a field strength of 0.5 oersted. A nominal or typical value is about 1.01 at 27°F. (1.004 at room temperature using a field strength of 200 oersteds).

The thermal expansion of MONEL Alloy 404 is about the same as that of MONEL Alloy 400, and is sufficiently close to that of many other alloys frequently used in the construction of radio tubes to permit the firing of composite metal structures with a negligible amount of distortion. MONEL Alloy 404 also retains much of its strength at "out-gassing" temperatures.

MONEL Alloy 404 is but one of a number of Huntington Alloys that are widely used in the electronics field. For further information on what these alloys are, where they are used, and in what forms they are available, write to the address below for the booklet, *Huntington Alloys for Electronic Uses.*

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MONEL®
NICKEL-COPPER ALLOYS

HUNTINGTON ALLOY PRODUCTS DIVISION
THE INTERNATIONAL NICKEL COMPANY, INC.
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30.4 Methods of Measurement of Noise

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4.3 Circuit Topology

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4.4 Linear Varying-Parameter and Non-Linear Circuits

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4.7 Linear Active Circuits Including Networks with Feedback Servomechanism

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7.3.2 Gas-Filled Radiation Counter Tubes

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7.4 Camera Tubes, Phototubes, and Storage Tubes in Which Photo-Emission is Essential

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J. S. Hickey — M. Uenohara
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7.5.4 Microwave Parametric Devices

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7.5.5 New High Power Electron Beam Devices

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7.5.6 Continuous Revision of Existing Standards

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W. J. Fleig — J. L. Putz
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7.5.7 Microwave Tunnel Diode Devices

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7.5.8 Definitions of Microwave Terms

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R. C. Wertman

7.6 Physical Electronics

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7.8 Camera Tubes

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with these Allen-Bradley A-B QUALITY quality electronic components

Mr. Design Engineer! When deciding upon components for your circuits, please remember that you can always be sure of obtaining *maximum reliability* with Allen-Bradley electronic components—and quality of production is consistent from one order to the next—and from one year to the next.

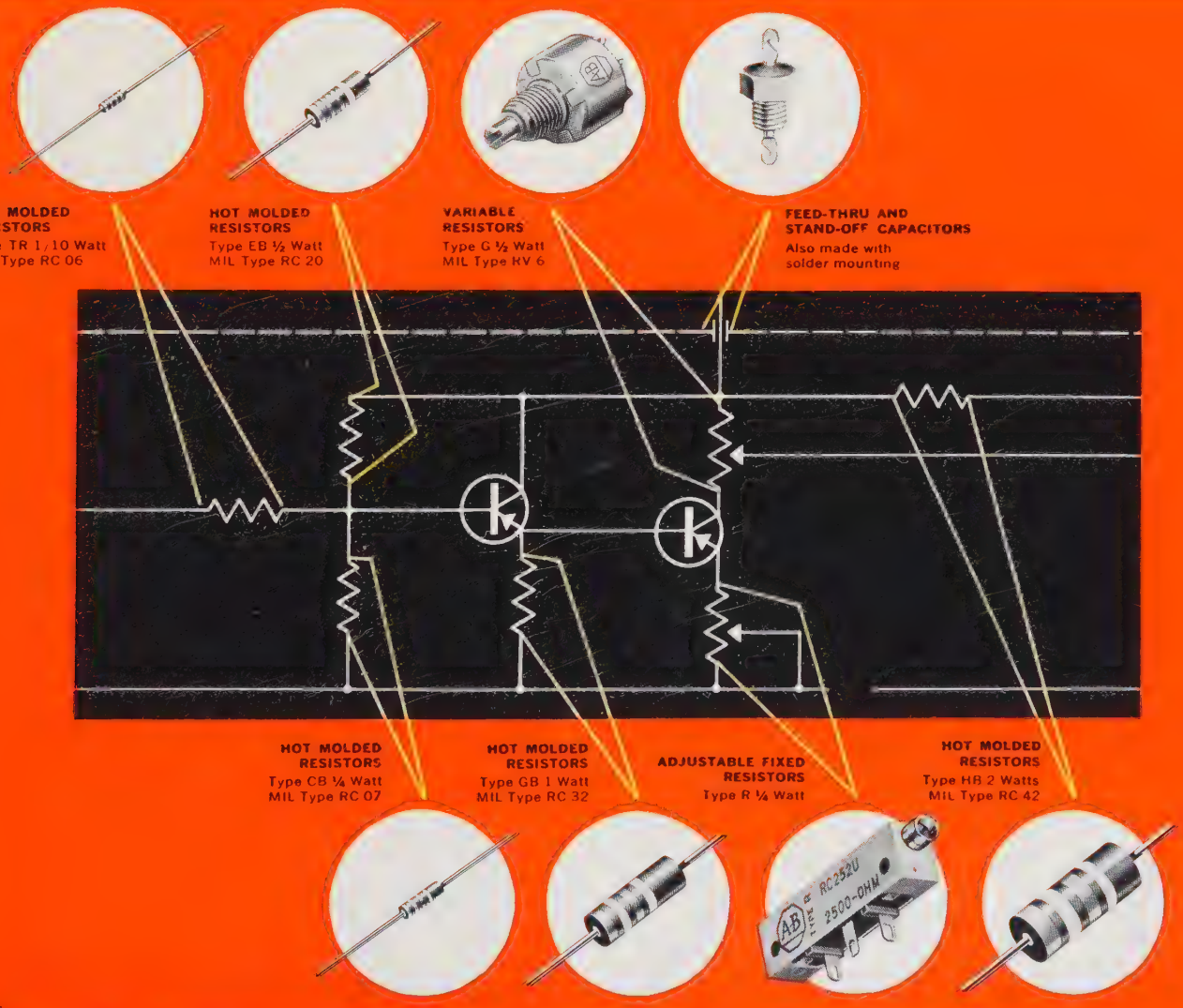
For example, Allen-Bradley fixed resistors—made by A-B's exclusive hot molding process—are famous for their conservative ratings, stable characteristics, and *complete freedom from catastrophic failures.*

Then there are the miniature Type G potentiometers. They feature a solid, hot molded resistance element that gives exceptionally long life and quiet operation which even improves with use. Control is always smooth—there are never any abrupt resistance changes during adjustment.

This same hot molding process is also used in making A-B's Type R adjustable fixed resistors, which provides "stepless" adjustment of resistance. In addition, the moving element is self-locking, resulting in absolutely stable settings.

Another "exclusive" is A-B's ceramic feed-thru and stand-off capacitors for use at VHF and UHF frequencies. With their *unique* discoidal design, all parallel resonance effects are eliminated at frequencies of 1000 mcps and less.

For details on the complete line of A-B *quality* electronic components, please send for Publication 6024.



6-62-E

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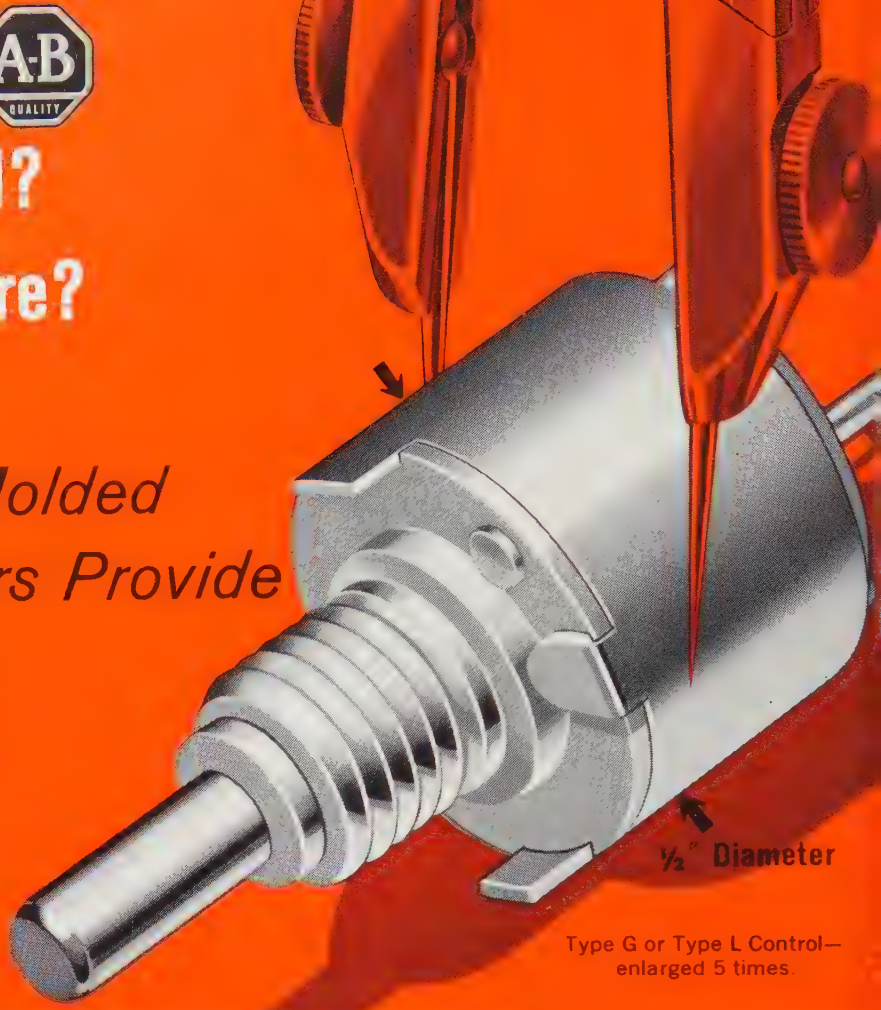
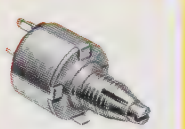
QUALITY ELECTRONIC COMPONENTS

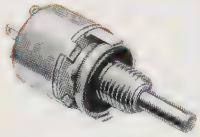
Space Restricted?
Application Severe?

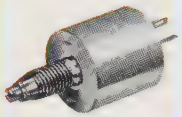
Allen-Bradley Miniature Hot Molded Variable Resistors Provide Smooth Control Which Improves With Use!

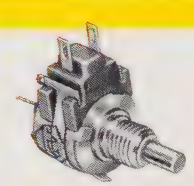


Type G or Type L Control—enlarged 5 times.


With locking bushing


With watertight panel seal


With encapsulation


With line switch

For board mounting

The same reliability and superior performance of Allen-Bradley's famous hot molded construction is found in this "space-saving" size. The solid resistance element, collector track, terminals and insulating material are all hot molded—by A-B's *exclusive* process—into a single solid structure. Molded contact brushes eliminate sliding metal contacts. This assures exceptionally low "noise" initially, and this quality feature improves with use. Incidentally, the operational life exceeds 50,000 cycles with less than 10% resistance change.

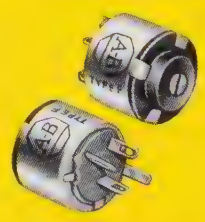
These miniature controls are available as:

Type G—For use over ambient temperature range from −55°C to +120°C. Rated 0.5 watt at +70°C.

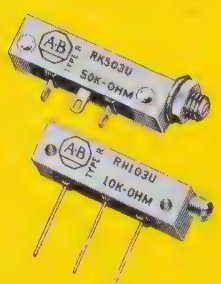
Type L—For use over ambient temperature range from −55°C to +150°C. Rated 0.8 watt at +70°C.

Both furnished in maximum resistances from 100 ohms to 5 megohms. For full details on these *quality* controls, please write for Technical Bulletin B5201.

ADDITIONAL A-B HOT MOLDED CONTROLS



The Type F controls are especially designed for printed board mounting. Terminals fit 0.1 inch spacing. Type F temperature range −55°C to +120°C, rated 0.25 watt at +70°C. Type O temperature range −55°C to +150°C, rated 0.4 watt at +70°C.



Type R adjustable fixed resistors allow stepless adjustment. Moving element is self-locking for absolutely stable settings. Watertight case permits encapsulation. For continuous use from −55°C to +125°C, rated 0.25 watt at +70°C.

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5-62-E

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H. G. Cooper
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D. Davis
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M. D. Harsh
H. Hook
A. S. Jensen
W. E. Kirkpatrick
J. Koda
W. R. Miller
H. M. Smith
M. de Thomasson
W. O. Unruh
S. Yanagisawa

7.11 Microwave Duplexer Tubes

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N. Cooper
L. Gould
F. Klawsnik
F. McCarthy
S. Miller
I. Reingold
J. Schussele
R. Scudder
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26.2 Methods of Measurements and Test of Feedback Control Systems

P. P. Fischer

26.3 Symbols and Terminology for Feedback Control Systems

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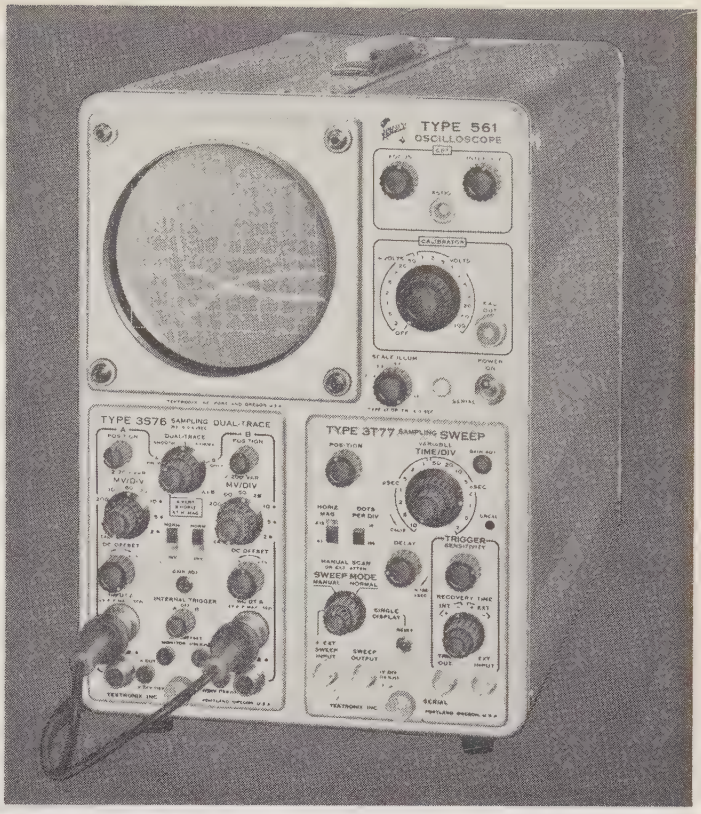

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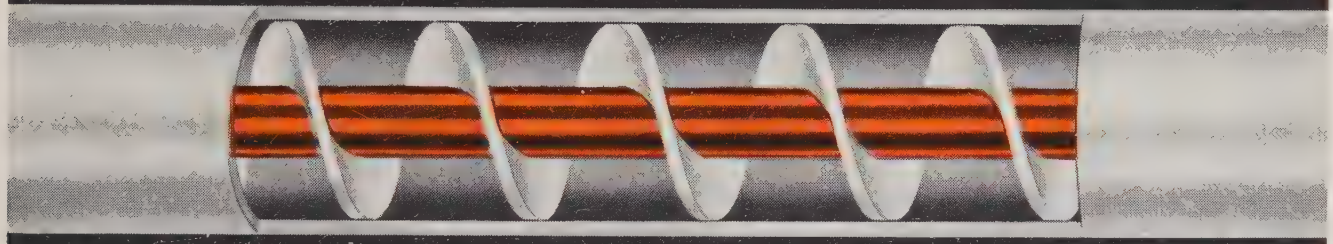

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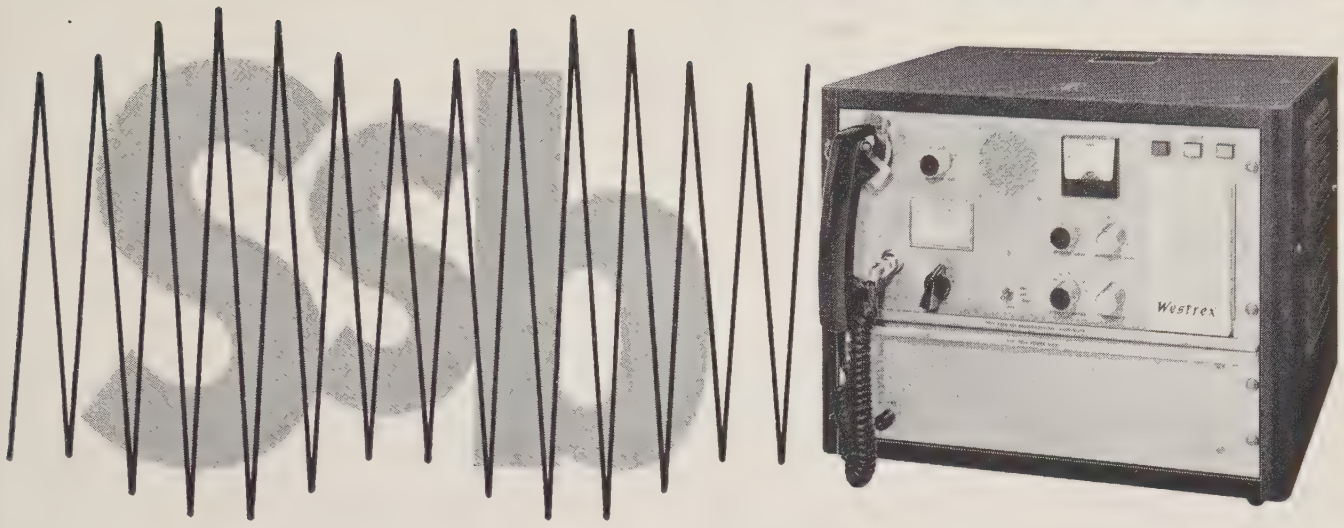

The most versatile ssb transceiver... Now with extended range, 2 to 18 megacycles, and improved performance specifications, plus these features —

- Choice of upper or lower sideband — just turn the switch
- Fully compatible operation on AM
- Semi-duplex operation if desired — transmit on one frequency, receive on another
- Built-in VOX
- Noise cancelling handset
- Built-in oscillator for transmitter line-up
- Designed for operation by non-technical personnel

Check these specifications

Power output 100 W PEP, 100 W CW, 25 W AM. Frequency stability ± 5 parts in 10^8, or ± 1 part in 10^6 with high stability oven. Third order non-linear distortion better than 36 db. Receiver sensitivity better than 0.5 uv at 2-15 mc, and 0.9 uv at 15-18 mc for 10 db S/N ratio. AGC characteristic less than ± 5 db variation in output for 60 db variation of input on SSB referred to 5 uv. Antenna matching network Pi-L type covering 30 to 300 ohm unbalanced. AF signal to harmonic distortion ratio better than 2% at 500 mW (400 cps). Antenna outputs 52-ohm BNC coaxial connector and standoff insulator for single wire use. **Write for complete details.**

Westrex Company

A DIVISION OF LITTON SYSTEMS, INC.
540 West 58th St., New York 19, New York.

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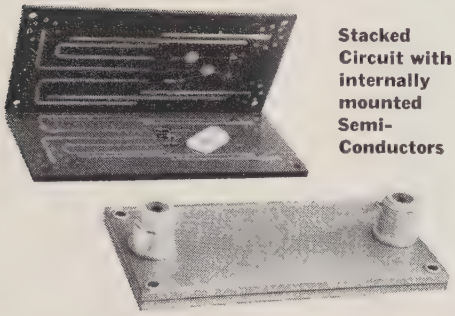

Stacked Circuit with internally mounted Semi-Conductors

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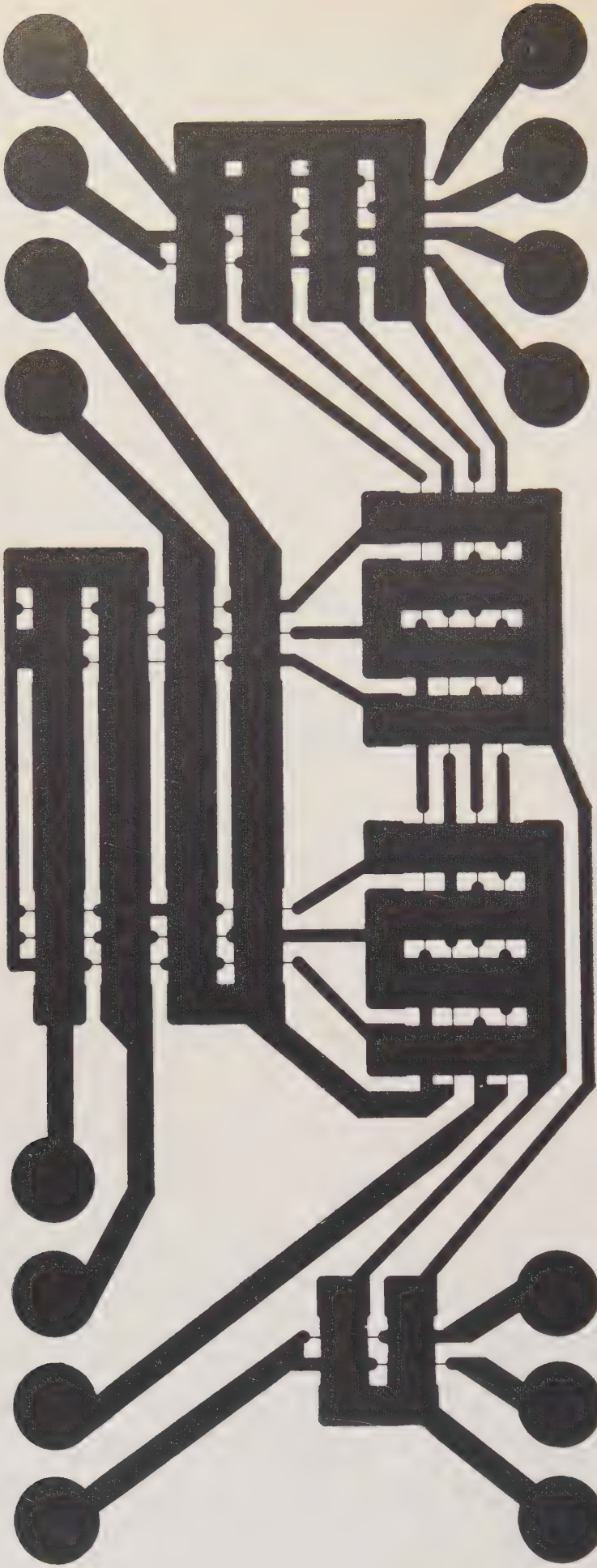
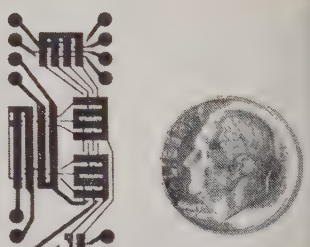
Line. ☐ Microwave Packages that heretofore have been thought impractical or impossible to build because of their bulk and complexity, are successfully produced in TRI-PLATE Line. For they match the performance of coaxial and waveguide circuits yet have a volume less than one-half, weigh less than one-fourth, and cost substantially less. What's more, TRI-PLATE Strip Transmission Line circuits have a packaging versatility to solve the most difficult problems. ☐ Reliability at Low Cost in TRI-PLATE Strip Transmission Line is a reality. Simplicity in construction, sound engineering techniques and automated production methods let you go from design to prototype to production with known characteristics. The advanced photo-etching process used in TRI-PLATE Strip Transmission Line provides a simple, fast and economical method of exact reproduction. ☐ For more information about strip transmission line and how TRI-PLATE Products have made it a practical reality, for the latest literature — including specifications and prices — or for consultation regarding your specific requirements, write to Sanders Associates, Inc., Microwave Products Dept., Nashua, New Hampshire.

CREATING NEW DIRECTIONS IN ELECTRONICS

SANDERS TRI-PLATE® STRIP TRANSMISSION LINE



GE NEWS



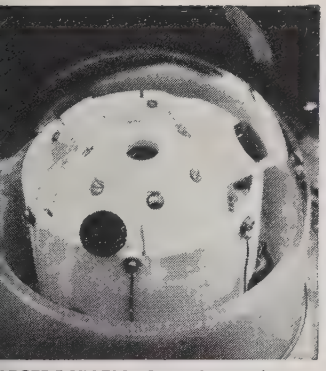
CRYOGENIC PROGRESS in inertial guidance is typified by this 32-gate logic element for smaller, faster, more reliable computers. Other current cryogenic work includes high-precision gyros and accelerometers.

GUIDANCE

There are vast differences between the techniques required to guide missile flights and those needed for space ventures. Entirely different problems are presented in the tasks of guiding an air-to-air missile having a few thousand yards range, sending an ICBM to a target thousands of miles away, and boosting men and instruments to the frontiers of space. Experience in each is invaluable in satisfying new mission requirements.

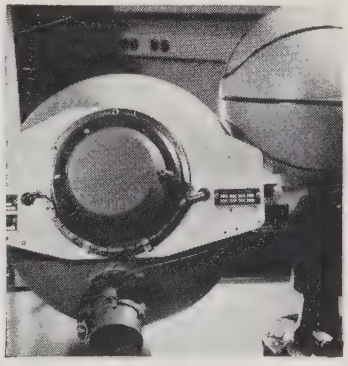
General Electric is producing infrared guidance for the Sidewinder, inertial guidance for the Polaris, and the radio-command system for Atlas ICBM's. It was this phenomenally accurate radio-command guidance that helped put the Mercury-Atlas into earth-orbit.

This wide range of guidance experience is enabling General Electric to apply new devices and techniques (such as electrostatic gyros and cryogenics) directly to existing problems, thus providing continuous and significant upgrading of guidance technologies and capabilities. Current activities include development of reference navigational systems for space and exploration of the best combinations of basic guidance forms for the sophisticated missiles and space vehicles of the future.

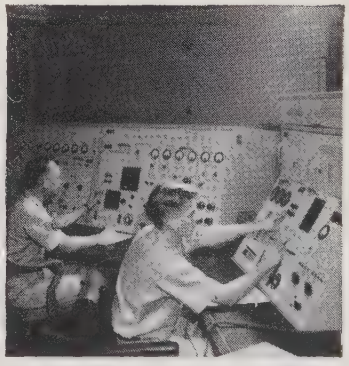


LECTROSTATIC GYROS are being eveloped to meet future require-ients for accuracies up to 1000 mes greater than those attainable ith present gyros. Other advan-ages will be simplicity and long life.

STAR-FIELD TRACKER correlates a viewed star pattern against a stored reference map for spacecraft attitude control. This device may replace the inertial table as an attitude sensor because of its zero drift.



INERTIAL GUIDANCE for Polaris has been extremely successful. Designed by M.I.T. and produced by General Electric, the small MK 2 system will help to extend the range of the advanced Polaris missile to 2500 miles.



RADIO-COMMAND GUIDANCE, already operational and proved accurate and reliable in ICBM and manned orbital flights, is currently being applied to booster programs and missile range instrumentation.

Progress Is Our Most Important Product

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DC STANDARD
ACCURATE
AND STABLE ENOUGH
TO CALIBRATE
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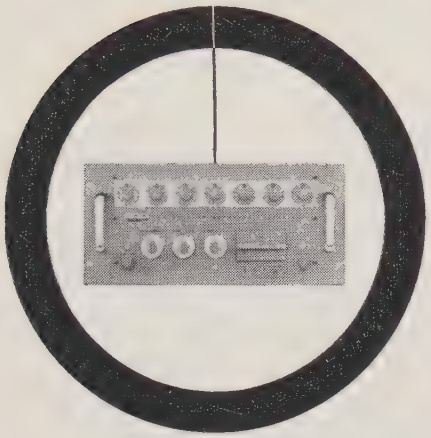

The KIN TEL Model 303
Voltage Standard

You can use this new standard for just about any laboratory or industrial application–including calibrating and testing digital voltmeters. It's that stable, that accurate! Seven decaded controls let you control output from zero to over ±1100 volts in steps as small as 1 μv. The output is accurate to within 0.01% of the dial setting and stable to within 0.005%. Resolution is within 0.1 part per million of full scale. With the 303, you can get up to 25 milliamperes of current on any voltage range, or you may limit the output by panel control to 5, 10, or 15 milliamperes. Separable sampling terminals provide effective source impedance *at the load* of 0.001 ohm. The output is floating and guarded. Price: $2995. F.O.B., San Diego. (50 cps operation at additional cost. Programmable, AC/DC and cabinet versions available at factory request.)

Representatives in all major cities.

COHU
ELECTRONICS, INC
KIN TEL DIVISION

5725 Kearny Villa Road, San Diego 12, California
Phone 277-6700 (Area Code 714)

Industrial Engineering Notes*

Association Activities

A total of 13,195,000 persons—7.2 percent of the nation's 186 million population—can receive telecasts from the 81 commercial ultra high frequency stations now on the air, according to a survey of UHF outlets prepared last week for the EIA Consumer Products Division. To illustrate how the television industry is supplying this market, the survey points out that 86,836 UHF-equipped receivers were produced during the first two months of this year, or 8.4 percent of the total output of 1,030,363 sets for the two-month period. The study, conducted by Division Staff Director L. M. Sandwick, disclosed that of the population served by the 81 commercial stations, 7,770,000 persons live in "UHF-only" areas, some of which also receive very high frequency telecasts from nearby communities. A total of 5,425,000 persons live in areas served by both UHF and VHF stations. The survey disclosed that 74 of the commercial stations have network affiliations. Five of the seven non-network stations have started or resumed operations within the last five months. Including the 81 commercial outlets, there are 104 UHF stations on the air. Others are: Educational, 18; religious, two; foreign language, one; and experimental, two. The survey lists commercial stations by states and information on other UHF stations in operation. A limited number of copies is available to EIA member-companies from Consumer Products Division, EIA Headquarters. Ask for "Listing of UHF Television Stations."

Governmental and Legislative

The Federal Communications Commission has ordered the use of single sideband transmissions by stations operating on frequencies below 30,000 kc in the International Fixed Public Radiocommunication Services after January 1, 1965. The new rule would not apply in cases where the foreign correspondent is unable to receive single sideband signals. The FCC action ended rulemaking in Docket 11513 . . . **The Commerce Department's Business and Defense Services Administration last week published "The U. S. Industrial Outlook for 1962: 94 Selected Industries," a compilation of the individual studies of key industries for 1961–62 issued earlier by BDSA.** The publication is available from the Government Printing Office, Washington 25, D. C. Price $1.50.

Industry Marketing Data

The total production of TV sets for January dropped about 100,000 sets from the December totals and radio declined about 500,000 from December figures, but both totals were up over the January 1961 statistics, according to the EIA Marketing Data Department. In January, 488,869 TV sets were produced against 580,262 in December. Output of 1,350,630 radios was reported for January compared with 1,845,206 the month before. TV production during the first month of 1961 totaled 367,935 and radio, 1,090,073 . . . **Total production of television sets in February increased considerably over that for January, according to the latest statistics released last week by the Marketing Data Department.** In February, 541,494 TV sets were produced against 488,869 in January. An output of 1,464,797 radios was reported for February, compared with 1,350,630 the month before. During the first two months of this year, 1,030,363 TV sets and 2,815,427 radios were produced. Last year during the same period, 812,353 television and 2,205,102 radios were reported . . . **Factory sales of transistors fell off 928,463 units in January, according to the EIA Marketing Data Department's monthly sales figures.** In January 17,238,376 transistors valued at $21,459,598 were sold, compared with December figures of 18,166,839 worth $24,883,538.

* The data on which these NOTES are based were selected by permission from *Weekly Reports*, issues of March 19, April 9 and 16, 1962, published by the Electronic Industries Association, whose helpfulness is gratefully acknowledged.

Neededness!*

More engineers *NEED Proceedings of the IRE* than need any other radio-electronic engineering magazine. 78,950 (ABC December 31, 1961) plus 17,385 students, to be exact. This is not promised—but delivered circulation.

* Engineers *NEED* the unabridged, factual, working information of which *Proceedings of the IRE* supplies over 1,900 pages a year. This is more than a WANT, but a vital need, satisfied since 1913 by

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a comprehensive guide to current information on every branch of Science and Technology

. . . a practical new way to bridge the gap between your specialty and other fields into which your work leads you

New from McGRAW-HILL

If you find yourself among the growing number of science and engineering specialists unable to keep up with the explosive pace of developments today, you will see a valuable solution at the top of this page.

Why use Ferrites?

Large quantities of ferrites are now being used in a wide variety of applications—operating in a frequency range of a few hundred cycles per second to several hundred megacycles per second. The growing popularity of ferrites is attributed to their desirable electrical or magnetic properties, and to the more economical cost of the component.

APPLICATIONS

Only a few years ago, engineering personnel probably considered ferrites as little above the experimental stage. Today their applications are considered infinite. Typical of such applications are their use in transformers, filters, delay lines, loading coils, modulation reactors, chokes, accelerators, pulse networks, pulse transformers, amplifiers, oscillators, antenna tuning devices, variable inductors, decoder and encoder discs, recording heads, memory cores, switch cores, turning slugs, a-c d-c, and d-c d-c converters, high-frequency lighting, and many specialized electronic devices. Continuing material advancements will extend ferrite applications in boundless proportions.

WANT TO LEARN ABOUT THEM?

Ferroxcube Corportion of America has prepared two technical brochures on the subject of ferrites and their applications. The first, *General Information on Ferrites* (Bulletin 101) provides ferrite material selectivity guides, recommended materials for new designs, basic characteristics of Ferroxcube ferrite materials, definitions, symbols and formulae related to the subject, and a resume of ferrite applications. The second brochure, *Why Use Pot Cores?* (Bulletin 201), describes pot core construction (with ferrite cores), and effects obtainable by "tailoring" ferrites.

YOUR R & D WITH FERRITES

So that you can investigate ferrites thoroughly without large investments, Ferroxcube has prepared over 30 sample kits of ferrite products for basic investigations, research and development. The kits—priced from $10.00 to $50.00—are described in detail in a third brochure *Ferroxkits.*

Free copies of these brochures are available on request.

FERRITES FIRST IN **FERROXCUBE**
CORPORATION OF AMERICA
SAUGERTIES, NEW YORK

FERROXCUBE CORPORATION of AMERICA
Saugerties, N.Y.

I am interested in:
☐ Bulletin 101
☐ Bulletin 201
☐ Ferroxkits

NAME_____

COMPANY_____

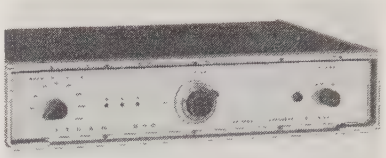
ADDRESS_____

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

Low Level Signal Converter

Featuring 5 mv sensitivity and 0.03% linearity, Series 260 low level, floating input converters are now available from **Vidar Corp.,** 2296 Mora Drive, Mountain View, Calif.

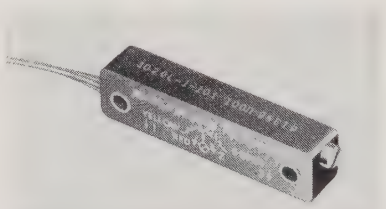


The new instrument operates without preamplification from all direct analog transducers including thermocouples, load cells, and other strain gage devices. Because input voltages are converted to proportional frequency, an existing frequency counter can be used to provide digital display of the input voltage magnitude. Precise integration of the transducer output can be accomplished by operating the counter as a totalizer. Overall conversion accuracy is 0.1%.

Priced at $1290 f.o.b. factory, Vidar 260 converters are available from stock to 30 days. For complete information, please address Vern Anderson at the firm.

Wirewound Potentiometer

A miniature, high-power wirewound potentiometer capable of operating at temperatures up to 200°C and of dissipating 5 watts at 25°C has been introduced by the Trimpot Div., **Bourns, Inc.,** 1200 Columbia Ave., Riverside, Calif.



Measuring only 1.25″×0.25″×0.328″, the new Model 3020 derates to only 3.75 watts at 70°C and 2 watts at 130°C. A ceramic mandrel which has the same coefficient of thermal expansion as the resistance wire eliminates breakage and strain gage effects. The resistance element is terminated by the patented, Silverweld® process.

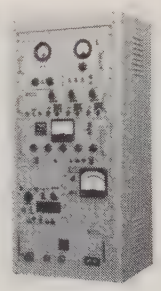
The aluminum housing of the 3020 acts as an efficient heat sink and will withstand cycling humidity per MIL-STD-202. A 25 turn adjustment permits close settings, while an idler mechanism at each end prevents damage from forced adjustment.

Specifications of the Model 3020 are: Resistance Range—100 to 50 K ohms, Power Rating—5 watts at 25°C, Electrical Rotation—25 turns nominal, Operating Temperature Range——65°C to 200°C, Vibration—Exceeds MIL-STD-202B, Method 204, Humidity—Meets MIL-STD-202, Method 106, Size—1.25″×0.25″×0.328″, Weight—0.19 ounce, Price—$10.40 (100 Pieces) f.o.b. Riverside.

The Model 3020 is immediately available from stock with stranded insulated leads or as a panel mount unit.

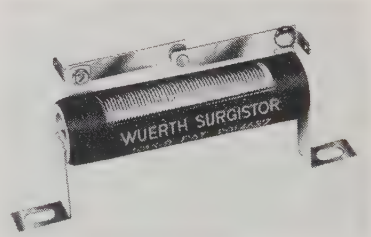
Synchro and Resolver Test Equipment

Kearfott Div., General Precision, Inc., manufactures synchro and resolver test consoles that are modularly constructed to permit the use of individual modules independent of the console. This equipment tests 115 or 26 volts, 400 cps synchro and resolver transmitters, differentials, and control transformers ranging in size from Size 5 through Size 25. Synchros are tested according to the specification of MIL-S-20708A, and resolvers are tested according to the specifications of MIL-R-21530. Typical tests performed include: phase sequence, null voltage (fundamental and total), transformation ratio, phase shift, perpendicularity, function error, and angular error.



Surge Control Device

A device for effective surge control of higher wattage electronic equipments called Surgistor is announced by **Wuerth Products Corp.,** 1949 Moffett St., Hollywood, Fla. Four entirely new high-power Surgistors will protect equipments drawing from 450 to 1500 watts at 117 volts, ac or dc.



The new "1000 series" Surgistors will

(Continued on page 56A)

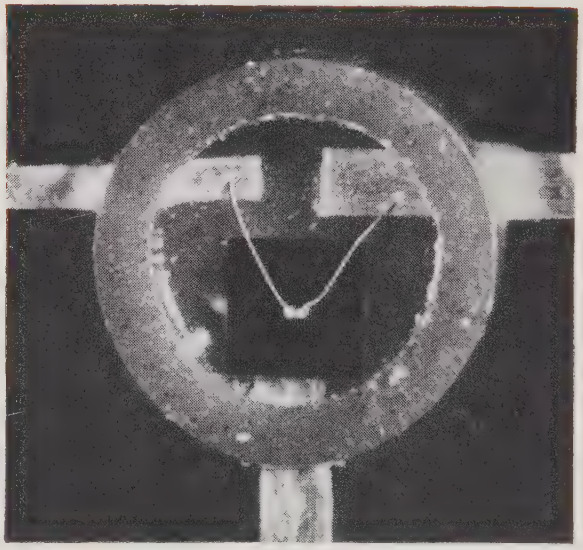
Now from Fairchild...

PLANAR FIELD EFFECT TRANSISTOR

high input impedance
low capacitance
low noise figure
low leakage current
TO-51 glass package*

Fairchild's new 2N2458 Field Effect Transistor features the ruggedness and stability of Fairchild Planar construction. Planar total surface passivation with patented metal-over-oxide techniques produces a device which is mechanically large enough for normal, reliable lead bonding techniques but at the same time electrically compact. Results: lower pinch-off voltage (V_p), lower leakage, and lower capacitance than any other field effect transistor. Complete specification sheet available on request.

*The Field Effect Transistor is also available in a standard TO-5 outline, designated the 2N2457.



MAGNIFIED 15 TIMES

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNITS	TEST CONDITIONS
BV_{DGO}	Drain to gate breakdown voltage	30	—	—	Volts	I_D=1.0μA, I_S=0
I_{DGO}	Drain to gate leakage current	—	—	0.1	mμA	V_{DG}=5.0V, I_S=0
I_{DGO} (150° C)	Drain to gate leakage current	—	—	0.1	μA	V_{DG}=5.0V, I_S=0
I_D	Saturation current	200	500	600	μA	V_{DS}=5.0V, V_{GS}=0
gm	Transconductance (f=1 kc)	125	200	—	μmhos	V_{DS}=5.0V, V_{GS}=0
NF	†Noise figure	—	0.4	—	db	V_{DS}=5.0V, V_G=0
V_p	Pinch-off voltage	—	3.0	4.0	Volts	I_D=0.1mμA
C_T	Total gate capacitance	—	0.7	1.0	pf	V_{DGS}=5.0V
Z_{in}	Input impedance (f=1 kc)	—	100	—	MΩ	V_{DG}=5.0V, V_G=0

†f = 1 kc, power bandwidth of 200 cps, R_S = 1 MEG Ω

FAIRCHILD

SEMICONDUCTOR

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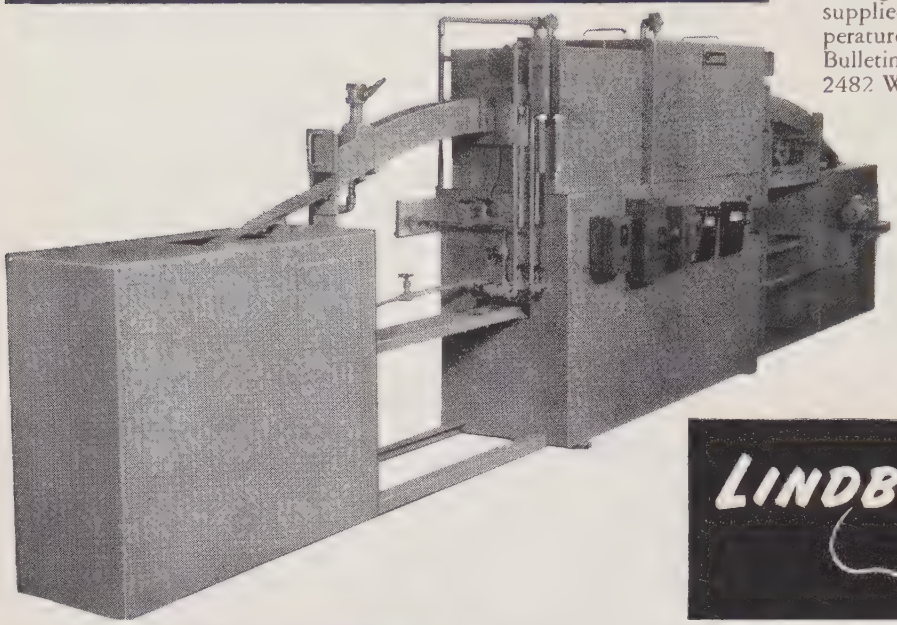
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

Lindberg Inclined Mesh Belt Furnaces for Alloying

This type furnace has been specifically designed by Lindberg for alloying, soldering and brazing applications for the semiconductor industry. Special metal resistor element design gives long element life and precise temperature control. Functional furnace construction and adequate insulation insure low shell temperatures. Alloy muffle and belt and precision drive provide precise control and product purity during processing cycle. Inclined or straight through mesh belt furnaces of this type can be supplied for any desired muffle dimension or temperature uniformity. For full information write for Bulletin No. 1083. Lindberg Engineering Company, 2482 West Hubbard Street, Chicago 12, Illinois.



This Lindberg Inclined Mesh Belt Furnace provides two individually heated chambers, preheat, 24" long (max. temp. 400°C.) rated at 7KW and high heat, 36" long (max. temp. 1000°C.). Water-jacketed cooling chamber is 72" long. Inconel alloy muffle and furnace hearth. Variable AC drive. Overall dimensions, 66" high, 25'10" long and 30" wide. Working dimensions 4" high over a 3" wide belt.

LINDBERG heat for industry

Engineers who know
—SPECIFY

Q-max*

A-27
SUPERFINE
LOW-LOSS RF LACQUER

• Q-max, an extremely low loss dielectric impregnating and coating composition, is formulated specifically for application to VHF and UHF components. It penetrates deeply, seals out moisture, provides a surface finish, imparts rigidity and promotes stability of the electrical constants of high frequency circuits. Its effect upon the "Q" of RF windings is practically negligible.

• Q-max applies easily by dipping or brushing, dries quickly, adheres well; meets most temperature requirements. Q-max is industry's standard RF lacquer. Engineers who know specify Q-max! Write for new catalog.

*Registered Trademark

Q-max Corporation
MARLBORO • NEW JERSEY
Telephone: HOpkins 2-3636

NEWS New Products

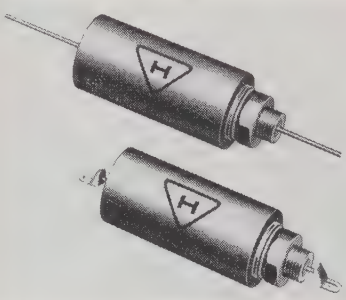
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 54A)

effectively control destructive inrush currents by simple connection in series with either power lead. The line voltage is initially reduced to about one third normal for approximately 10 seconds after which time full line voltage is automatically restored by a self-contained thermal switch.

Over-all dimensions including the mounting brackets are: $1\frac{5}{8}$" high, $3\frac{5}{8}$" long, and $\frac{5}{8}$" wide. Net weight is one ounce. Price: List price $4.90; production prices on request.

Miniature Feed-Thru Capacitors



A new series of miniature feed-thru capacitors are available in paper, Mylar and polystyrene dielectrics from **Hopkins Engineering Co.,** 12900 Foothill Blvd., San Fernando, Calif. They are designed for use in radio interference suppression for radar, communications and other installations. Attenuation characteristics are good as the reactance closely matches the curve of an ideal capacitor through all frequencies up to 1000 mc. Units are hermetically sealed in non-magnetic tubular cases with glass-to-metal seals to meet or exceed requirements of MIL-C-25A characteristic "K" 125°C operation. The 0.05 capacity series range in lengths of 0.875 to 1.375 in. and diameters from 0.312 to 0.562 in. Other capacities and relative dimensions are 0.1; 0.25; 0.5 and 1.0. Temperature: −55 to +125°C. Power factor: Will not exceed 0.5% measured at 1000 cps and 25°C. Capacitance stability: +3% from −55°C to 125°C. For complete physical and electrical specifications, write to John Schlenker, sales manager.

Power Dividers

Smaller, lighter phased-array radar systems are now possible with two new Epsiline series of eight- and 16-way microwave power dividers developed by the Instrument Division of LFE Electronics, a major operating group of Boston-based **Laboratory For Electronics, Inc.,** 1079 Commonwealth Ave., Boston 15, Mass.

The devices are completely encapsulated to limit the effects of radiation, moisture, corrosion, shock and vibration damage.

(Continued on page 58A)

For the 10TH year...

LAMBDA OFFERS THE STRONGEST PROOF OF TROUBLE-FREE POWER SUPPLY PERFORMANCE

Every Lambda power supply sold since 1953 has been backed by Lambda's 5-year guarantee, which covers workmanship and materials (except for tubes and fuses). Any Lambda power supply sold today is guaranteed to perform to specifications until 1967.

5-Year
Guarantee
We warrant each instrument manufactured by us, and sold by us or our authorized agents, to be free from defects in material and workmanship and that it will perform within applicable specifications for a period of five years after original shipment. Our obligation under this guarantee is limited to repairing or replacing any instrument or part thereof, (except tubes and fuses) which shall, within five years after delivery to the original purchaser, be returned to us with transportation charges prepaid, prove after our examination to be thus defective.
We reserve the right to discontinue instruments without notice, and to make modifications in design at any time without incurring any obligation to make such modifications to instruments previously sold.
Ready for Long Dependable Service
In choosing this Lambda Power Supply, you are benefitting from an outstanding record of performance measured under the most grueling field conditions.
Long-term, trouble-free operation in heavy-duty service, attested to by owners and users of Lambda Power Supplies, has made possible the unprecedented five-year guarantee that covers this piece of equipment.
LAMBDA ELECTRONICS CORP.
YEAR GUARANTEE

ALL-TRANSISTORIZED LA SERIES
Nine Models Available—Voltages
up to 330 VDC—Currents up to 20 Amp
Convection Cooled—Short Circuit Proof

Send for Catalog on LAMBDA'S
wide range line of regulated
transistorized power supplies

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Western Regional Office: 230 North Lake Avenue, Pasadena, California • Phone: Code 213, MUrray 1-2544
New England Regional Office: 275 Boston Post Road, Marlboro, Massachusetts • Phone: Code 617, HUntley 5-7122
Middle Atlantic District Office: 515 Broad Hollow Road, Huntington, L. I., New York • Phone: Code 516, MYrtle 4-4200
Southeastern Region: W. A. Brown & Associates, Inc., Engineering Representatives LA-128-A

IS *YOUR* COMPANY ON THE *OFFENSE* FOR *DEFENSE?*

SIGNAL is your introduction to the men who control government's growing $6.5 billion radio-electronics spending

Never before have our armed forces so badly needed the thinking and products of the electronics industry. Advertising in SIGNAL, the official journal of the *Armed Forces Communications and Electronics Association*, puts you in touch with almost 11,000 of the most successful men in the field—every one a prospect for your defense products!

Share in the defense and the profits! Company membership in the AFCEA, with SIGNAL as your spokesman, puts you in touch with government decision-makers!

SIGNAL serves liaison duty between the armed forces and industry. It informs manufacturers about the latest government projects and military needs, while it lets armed forces buyers know what *you* have to offer to contribute to our armed might. SIGNAL coordinates needs with available products and makes developments possible.

But SIGNAL is more than just a magazine. It's *part of an over-all plan!*

A concerted *offensive* to let the government, which has great faith in industry and the private individual producer, know exactly what's available to launch its far-sighted plans. Part of this offensive is the giant AFCEA National Convention and Exhibit (to be held this year in Washington, D.C., June 12-14). Here, you can *show* what you have to contribute directly to the important buyers. Your sales team meets fellow manufacturers and military purchasers and keeps "on top" of current government needs and market news.

Besides *advertising* in SIGNAL which affords year-round exposure by focusing your firm and products directly on the proper market . . . besides *participation* in the huge AFCEA National Convention and Exhibit . . . the over-all plan of company membership in the AFCEA *gives your firm a highly influential organization's experience and prestige to draw upon.*

As a member, you join some 175 group members who feel the chances of winning million dollar contracts are worth the relatively low investment of time and money. On a local basis, you organize your team (9 of your top men with you as manager and team captain), attend monthly chapter meetings and dinners, meet defense buyers, procurement agents and sub-contractors. Like the other 60 local chapters of the AFCEA, your team gets to know the "right" people.

In effect, company membership in the AFCEA is a "three-barrelled" offensive aimed at putting your company in the "elite" group of government contractors —the group that, for example in 1957, for less than $8,000 (for the full AFCEA plan) made an amazing total of *459.7 million dollars!*

This "three-barrelled" offensive consists of

(1) Concentrated advertising coverage in SIGNAL, the official publication of the AFCEA;

(2) Group membership in the AFCEA, a select organization specializing in all aspects of production and sales in our growing communications and electronics industry; and

(3) Attending AFCEA chapter meetings, dinners and a big annual exposition for publicizing your firm and displaying your products.

If *you're* in the field of communications and electronics . . . and want prestige, contacts and exposure . . . let SIGNAL put your company on the *offense* for *defense!* Call or write for more details—now!

SIGNAL

Wm. C. Copp & Associates
72 West 45th Street,
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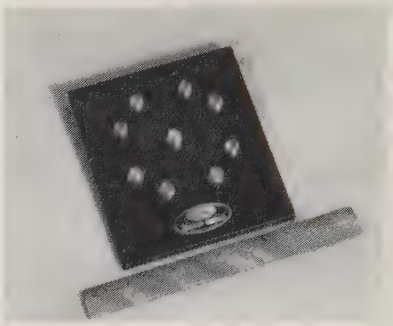
Boston · Chicago · Minneapolis · Los Angeles · San Francisco

BPA

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 56A)

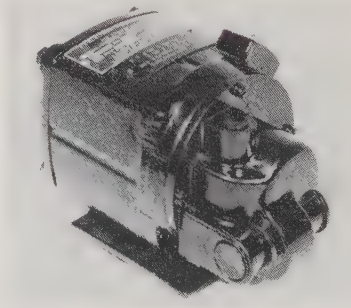


Each of the five models of eight-way power dividers shown by LFE measures 7 11/16 inches wide by 8⅝ inches long by 9/16 of an inch thick and weighs 24 ounces. The five models of 16-way microwave power dividers measure 11 inches wide by 12 inches long by 9/16 of an inch thick and weigh 36 ounces each. Working from 5 different models, frequencies range from 3600 to 6600 mc.

Standard specifications for all units include: input and output impedance—50 ohms; input and output VSWR, maximum—1.5 to 1; output power balance—±0.5 db; port-to-port isolation—35 db average, 20 db minimum; absolute decoupling, input and output—9.5 db ±0.5 db for eight-way dividers and 12.5 db for 16-way dividers: phase unbalance between outputs—±6.0 degrees; maximum CW power at band edges—100 watts.

Sub-Fractional HP Gearmotor

Holtzer-Cabot Corp., 125 Amory St., Boston 19, Mass., now offers its CB-37 line of explosion-proof, sub-fractional horsepower motors with integral right-angle gear reductions. These units are approved by UL for use in Class I, Group D and Class II, Groups F and G hazardous environments.



CB-37 gearmotors are available in induction or synchronous types, single or polyphase, in ratings from 1/100 to 1/15 hp. Thirty reduction ratios are available, from 8:1 to 4464:1, with speeds from 0.4 to 225 rpm. Torques vary from 0.7 to 45 lb/in.

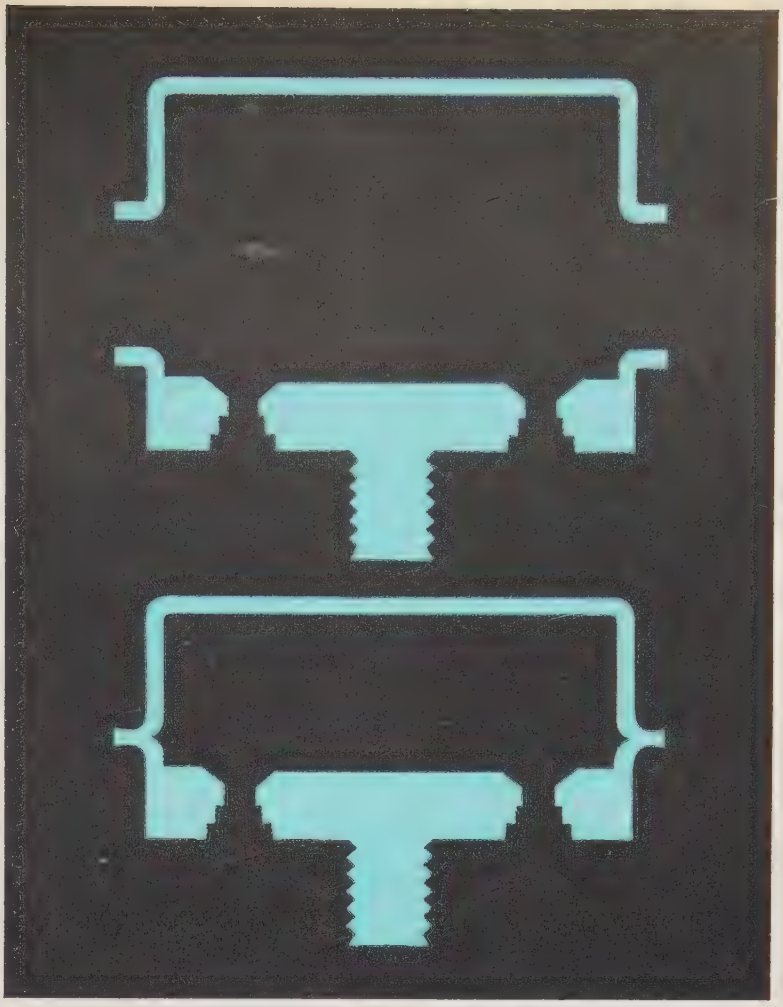
For complete information contact the firm.

(Continued on page 144A)

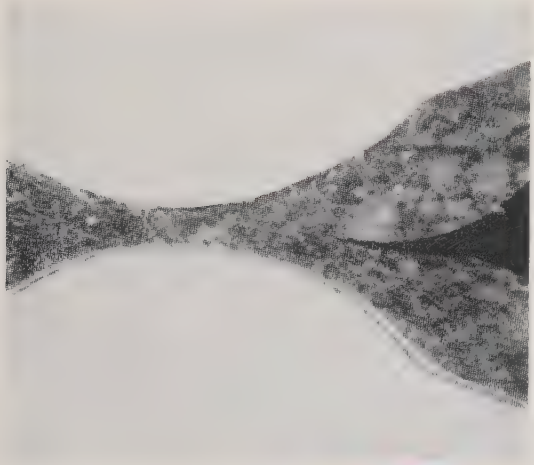
TUNG-SOL COLD WELDS OFHC* CASES

TO PRODUCE POWER TRANSISTORS THAT DELIVER FULL POWER

*Oxygen Free, High Conductivity



To be Cold-Welded, the flanges of the transistor can must be free of contaminants. The two surfaces are united under evenly distributed high pressure, causing copper molecules to flow together, producing an unbreakable, hermetic seal. Photomicrograph (45X) reveals absence of seam or interface. In addition to photomicrographs, Tung-Sol non-destructively tests weld quality with 100-psi water bomb immersion, mass spectrometer and radioactive tracer tests.



Cold-Welded germanium power transistors originated with Tung-Sol. The Cold-Weld process provides Tung-Sol transistors (in all case styles) with several significant advantages over transistors sealed by other techniques:

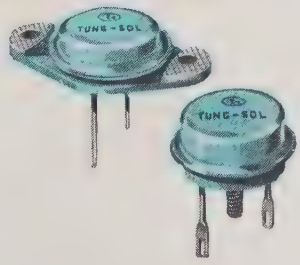
A seamless molecular bond between can and header improves thermal properties. Hot spots are eliminated, preventing reduction in power output or degradation of the semiconductor. The oxygen-free, high-conductivity copper provides superior heat conduction and is compatible with other device parts.

Cold-Welding prevents heat-caused damage during production, contributing to longer life and optimum performance. There are no "splash"-produced fragments, which, if undetected during factory tests, could short the transistor in operation.

Temperature fluctuations due to environmental changes, or on-off operations, cannot cause "breathing". The seam-free molecular bond excludes moisture and cannot be torn apart by mechanical stress.

Cold-Welding typifies the advanced design and production techniques employed by Tung-Sol in the manufacture of power transistors. Characteristics such as thermal resistance (K factor) are based upon the most meaningful combination of environmental and electrical tests. Design center ratings are given for junction temperatures of 110°C, 10 degrees above usual requirements. Saturation voltages are lower and breakdown voltages higher than in ordinary transistors. Mounting surfaces are flat-ground to provide full contact with heat sinks.

These features are present in all Tung-Sol TO-3 and TO-36 configurations. Write for design information. Tung-Sol Electric Inc., Newark 4, New Jersey. TWX:NK193.

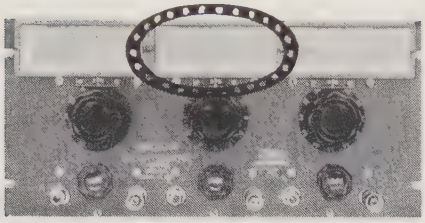


TUNG-SOL® FULL POWER
POWER TRANSISTORS

From WEINSCHEL

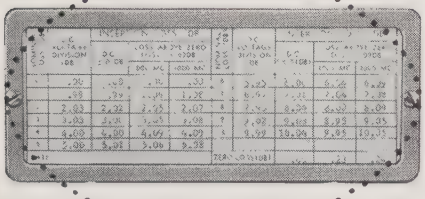
EXTENDED RANGE

More Accurate Calibration



Model 64A

PRECISION STEPATTENUATOR



Specifically designed to meet your most exacting requirements for accuracy and reliability, the Model 64A Stepattenuator, covering the range from 0 to 64 db in 0.1 db steps, includes these exclusive Weinschel features:

NEW Calibration data of the highest commercially available accuracy—0.02 db per 10 db—permanently mounted on the front panel for **fast, easy** reference

NEW Actual operable frequency range —DC to **2 KMC**

NEW Simplified readout

NEW One male and one female Type N connector for each drum to reduce the need for adapters

For complete specifications on the Model 64A Precision Stepattenuator, or for information on special models to meet other requirements, contact our Application Engineering Department.

WEINSCHEL ENGINEERING

WEINSCHEL

10503 METROPOLITAN AVENUE
KENSINGTON, MARYLAND
Tel.: 949-0141 (Area Code 301)
TWX: KENS 446
In California: 631 Wilshire Blvd.
Santa Monica
TWX: SMON 7185

IRE People

W. P. Maginnis (SM'45) has joined the Electro-Tec Corp., West Caldwell, N. J., as Executive Vice President. Prior to assuming his new post. Mr. Maginnis was Vice President of Maxson Electronics Corp., New York, N. Y., Vice President of ITT's Components Division, Clifton, N. J., and also Chief Engineer of the Components Division of RCA, Camden, N. J.

W. P. MAGINNIS

❖

Richard R. Martin (A'48–M'55–SM'57) was recently elected President of the newly formed Decision Systems, Inc., Silver Spring, Md.

He has been employed for the past eight years by IBM and was responsible for the design of production SAGE computer and input-output system. He was also responsible for advanced development programs in magnetic drums, transistorized magnetic tapes, multi-channel input system, reliability techniques and advanced system techniques; and most recently he served as a member of their Product Planning Staff, Federal Systems Division, Rockville, Md.

As a Lieutenant in the U. S. Naval Reserve during the Korean War, he was assigned to the U. S. Naval Computing Machine Laboratory, St. Paul, Minn., as a technical liaison officer on a large special purpose computer project.

Mr. Martin graduated in 1945 from the Massachusetts Institute of Technology with an S.B. degree in electrical engineering. He also attended Syracuse University and received a Master's degree in electrical engineering in 1957. He attended the IBM Executive Development School, and is a licensed Professional Engineer in New York State.

Mr. Martin is a senior member of ISA, and a member of the National Society of Professional Engineers.

❖

Thomas I. Paganelli (SM'55) has been named General Manager of the General Electric Company's Heavy Military Electronics Department, Syracuse, N. Y. In his new position he will be responsible for directing one of General Electric's largest defense electronics departments. He was formerly manager of the Department's Systems Operation.

During the past twenty years, Mr. Paganelli has gained recognition throughout military and industrial circles for both his system management and engineering leadership in the long-range missile detection and air defense fields.

He was appointed Manager of the Heavy Military Electronic Department's Systems Operation in 1961.

From 1957 to 1961, as Manager of the Department's Missile Detection Systems Section, he directed the company's efforts on several key defense projects, including the AN/FPS-17 missile detection radar systems.

Graduated from the University of California in 1942 with a Bachelor's degree in electrical engineering, Mr. Paganelli served in the U. S. Air Force and on the staff of the Massachusetts Institute of Technology's Servomechanisms Laboratory before joining General Electric's marine radar engineering unit at Syracuse, N. Y., in 1950.

❖

John M. Phelps (SM'59) Captain USN (Ret.) has been named Vice President-Operations of Granger Associates, Palo Alto, Calif. He will have overall responsibility for manufacturing, supply, quality assurance and field services.

Captain Phelps, who retired from the Navy in 1961 after 27 years of active duty, joined the communications equipment firm that year as Assistant to the President.

In his last two active duty assignments he was Commanding Officer and Director of the Navy Electronics Laboratory at San Diego from 1956 to 1960 and was Director of Research and Development of the Defense Communications Agency during 1960 and 1961.

His previous experience includes 14 years in technician and management positions in naval shipyards and in the Bureau of Ships, with assignments as head of the bureau's Components Section, Systems Branch and Electronic Design Division.

A graduate of the U. S. Naval Academy in 1934, Captain Phelps also was graduated from the Naval Post-Graduate Course in electronics engineering in 1942. He is a member of the Armed Forces Communications and Electronics Association and the U. S. Naval Institute.

❖

Donald A. Peterson (A'55–M'59) has been appointed an engineering specialist at the Reconnaissance Systems Laboratory of Sylvania Electric Products Inc., Mountain View, Calif.

Mr. Peterson, who has been with the Reconnaissance Systems Laboratory since 1958, is supervisor of an information processing group working on a special Air

(Continued on page 62A)

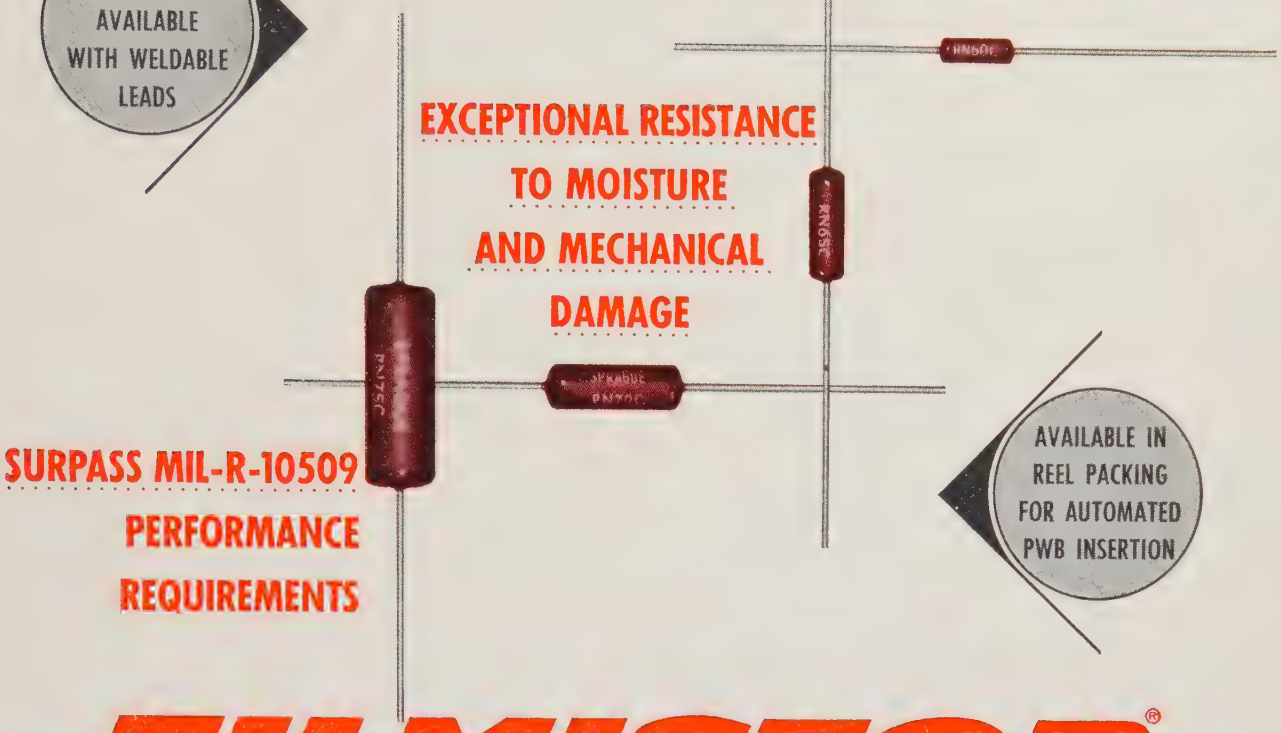
RUGGED END-CAP CONSTRUCTION FOR LONG TERM STABILITY

NOW AVAILABLE WITH WELDABLE LEADS

EXCEPTIONAL RESISTANCE TO MOISTURE AND MECHANICAL DAMAGE

SURPASS MIL-R-10509 PERFORMANCE REQUIREMENTS

AVAILABLE IN REEL PACKING FOR AUTOMATED PWB INSERTION



FILMISTOR®

METAL FILM RESISTORS

OFFER 5 DISTINCT TEMPERATURE COEFFICIENTS TO MEET ALL CIRCUIT REQUIREMENTS

Providing close accuracy, reliability and stability with low controlled temperature coefficients, these molded case metal-film resistors outperform precision wirewound and carbon film resistors. Prime characteristics include minimum inherent noise level, negligible voltage coefficient of resistance and excellent long-time stability under rated load as well as under severe conditions of humidity.

Close tracking of resistance values of 2 or more resistors over a wide temperature range is another key performance characteristic of molded-case Filmistor Metal Film Resistors. This is especially important where they are used to make highly accurate ratio dividers.

Filmistor Metal Film Resistors, in ⅛, ¼, ½ and 1 watt ratings, surpass stringent performance requirements of MIL-R-10509D, Characteristics C and E. Write for Engineering Bulletin No. 7025 to: Technical Literature Section, Sprague Electric Co., 235 Marshall Street, North Adams, Mass.

For application engineering assistance write:
Resistor Division, Sprague Electric Co., Nashua, New Hampshire.

SPRAGUE COMPONENTS

RESISTORS	INTERFERENCE FILTERS	HIGH TEMPERATURE MAGNET WIRE
CAPACITORS	PULSE TRANSFORMERS	CERAMIC-BASE PRINTED NETWORKS
MAGNETIC COMPONENTS	PIEZOELECTRIC CERAMICS	PACKAGED COMPONENT ASSEMBLIES
TRANSISTORS	PULSE-FORMING NETWORKS	FUNCTIONAL DIGITAL CIRCUITS

SPRAGUE®
THE MARK OF RELIABILITY

'Sprague' and '®' are registered trademarks of the Sprague Electric Co.

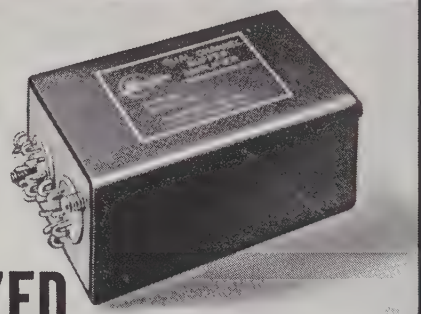
SIZE 11 WINDING-COMPENSATED SYNCHRO RESOLVER

Precision, lightweight, high-accuracy components with applications in analog computers and automatic control systems. The compensator winding provides feedback voltage for a resolver isolation amplifier; the feedback loop automatically adjusts to compensate for temperature and frequency variations. Function error of the R980-018 is only 0.1%. A compatible transistorized amplifier, Kearfott number S3100-01A, is available.

	Part Number	5R980-41	CR9 0980 001 R980-018
CHARACTERISTICS	Excitation (volts) (max.)	60	26
	Frequency (cps)	400	400
	Total Null Voltage (mv)	25	10
	Max. Error from E.Z. (minutes)	5	5
	Operating Temp. Range (°C)	−55 to +125	−55 to +125

For complete data write Kearfott Division, General Precision, Inc., Little Falls, New Jersey.

KEARFOTT



DUAL-CHANNEL TRANSISTORIZED BUFFER AMPLIFIERS

These high-performance units are designed to drive Kearfott's Size 11 R980 winding-compensated synchro resolvers. The amplifier-resolver combination has stable gain characteristics and negligible phase shift through an ambient temperature range of −50°C to +85°C. Extremely high resistance to shock and vibration. Meet environmental requirement of MIL-E-5272.

	Part Number	S3100-01
	Number of Inputs	4 per channel
	Input Impedance (ohms resistive at 25 C)	100,000
CHARACTERISTICS	Voltage Gain	1±0.0005
	Phase Shift (rotor output to input at 25 C)	less than 15 min.
	Max. Signal Output Voltage	16 volts
	Gain Stability Over Operating Temp. Range	1±0.05%

For complete data write Kearfott Division, General Precision, Inc., Little Falls, New Jersey.

GENERAL PRECISION

IRE People

(Continued from page 60A)

Force program. He was an advanced development engineer prior to his new appointment.

His electronics experience includes work on miniaturized, airborne and spaceborne computers with Librascope, Inc. Glendale, Calif. and research in and development of ballistic computers as an assistant physical scientist with the U. S. Army Ordnance Corps, Aberdeen Proving Grounds, Md.

A graduate of the University of Minnesota with Bachelor's degrees in science and physics, Mr. Peterson is a member of the American Physical Society.

❖

Wyle Laboratories' Ransom Research Division, San Pedro, Calif., has announced the addition of **Joseph Deutsch** (A'52–SM'58) to the staff as Assistant to the General Manager.

J. DEUTSCH

Prior to joining Ransom Research, Mr. Deutsch was Manager of the Data Processing Department at Aeronutronic, a division of Ford Motor Co.

Mr. Deutsch's formal education includes a B.A. degree in physics and mathematics from Brooklyn College, a B.S. degree in electrical engineering from Pennsylvania State University, and graduate work at George Washington University and at the University of Pennsylvania. He is a member of AIEE, AEM, and RESA.

❖

Paul Edward Ritt, Jr. (M'57) has been named Vice-President-Research of Melpar, Inc., Falls Church, Va.

P. E. RITT, JR.

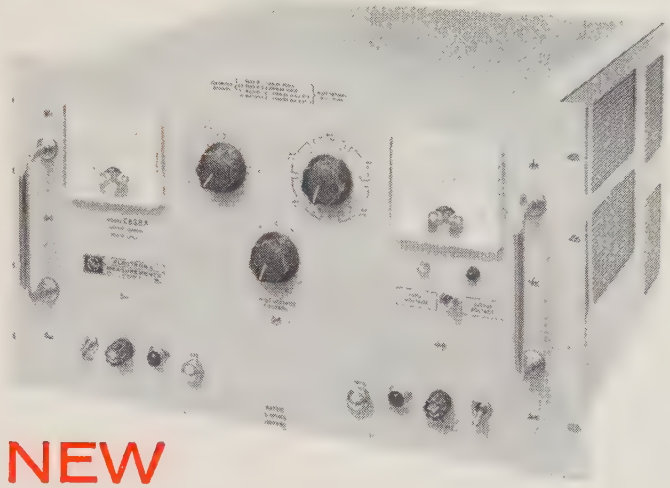
Formerly Melpar Research Director, Dr. Ritt joined Melpar as an engineer in the Chemistry Lab in 1952, and rose steadily to his current position.

Dr. Ritt has published a total of 40 technical papers and has been granted five patents. He has served on the staffs of the University of Virginia and American University, has appeared on television science education programs and has made films on scientific subjects for the Ford Foundation for use in schools.

He is a member of 16 professional societies, and has been elected to the Washington Academy of Science and the Geophysical Union. Both in 1960 and 1961, Dr. Ritt was nominated one of the Ten

(Continued on page 64A)

only ELECTRONIC MEASUREMENTS



NEW CONSTANT-CURRENT POWER SUPPLIES

*offer all these exclusive features:**

1. **Constant-current from less than 0.5 microampere up to 3 A.**
2. **Models to 1500 V DC compliance.**
3. **Voltage-limiting control to limit compliance.**
4. **Remotely programmable.**
5. **Modulation input . . . power supply can also be used as general purpose or operational amplifier.**

Electronic Measurements Constant-Current Power Supplies were designed specifically for constant-current output. In this respect, they offer advantages in the field of semiconductor work that can't be matched by conversions of constant-voltage (voltage-regulated) power supplies . . .
Ask for Specification Sheet 3072C for all the facts.

*BRIEF SPECIFICATIONS

MODEL	CURRENT RANGE		†VOLTAGE COMPLIANCE AT	
	MIN.	MAX.	MAX. I	MIN. I
C612A	1 μa	100 ma.	260 V	100 V
C631A	1 μa	100 ma.	420 V	300 V
*C638A	0.5 μa	100 ma.	2100 V	1500 V
C624A	2.2 μa	220 ma.	260 V	100 V
C632A	2.2 μa	220 ma.	420 V	300 V
*C636A	2.2 μa	220 ma.	735 V	600 V
C629A	2.2 μa	300 ma.	205 V	150 V
C633A	2.2 μa	300 ma.	420 V	300 V
C620A	5 μa	500 ma.	110 V	50 V
C621A	5 μa	500 ma.	160 V	100 V
C613A	10 μa	1 AMP	115 V	50 V
C614A	10 μa	1 AMP	170 V	100 V
*C628A	10 μa	1 AMP	215 V	150 V
*C630A	10 μa	1 AMP	280 V	200 V
*C625A	22 μa	2 AMP	150 V	75 V
*C626A	22 μa	2 AMP	190 V	100 V
*C615A	22 μa	3 AMP	125 V	50 V
*C618A	22 μa	3 AMP	170 V	100 V

* Voltage limiting control standard. Optional on all other models.
† For current vs. voltage compliance curves, request Specification Sheet 3072C.

ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

HOW TO MAKE A MAGIC TEE PERFORM FROM 2 TO 4 Gc

Sage Laboratories' Model 773 Coaxial Magic Tee uses strip transmission techniques to achieve a minimum operating bandwidth from 2 to 4 Gc. Model 773 is a four-terminal device which operates as a classical magic tee. It has many applications as a simple coupler or power divider, and can be used as the basic component in the design of balanced mixers, balanced duplexers, variable phase shifters, variable attenuators, and monopulse packages.

Model Number: 773
Frequency Range: 2.0 to 4.0 Gc
Coupling: 3 db ± 0.6 db maximum
Isolation: 25 db minimum
Insertion Loss: 0.25 db nominal
VSWR, all ports: 2.0 maximum
Peak Power: 5 KW nominal
Average Power: 100 Watts nominal
Price: $175.00 — subject to change

Sage Laboratories is prepared to produce similar units in other bands, using frequency-scaling techniques. Send today for complete data. No microwave prestidigitator should be without it.

SAGE LABORATORIES, INC.
3 HURON DRIVE • NATICK, MASS.
Cable Address: WARWICK — BOSTON

IRE People

(Continued from page 62A)

Young Outstanding Men of the Year by Northern Virginia Junior Chamber of Commerce Organizations.

He received his Ph.D. degree from Georgetown University in 1954 and his M.S. degree there in 1952. He graduated from Baltimore's Loyola College with a B.S. degree in 1950.

❖

It has been announced that **Dr. Yardley Beers** (A'44–M'46) and **Dr. George E. Schafer** (SM'57) will head the two newly created divisions within the Radio Standards Laboratory of the National Bureau of Standards, Boulder, Colo.

Dr. Beers will serve as Chief of the Radio Physics Division, and Dr. Schafer will serve as Chief of the Circuit Standards Division.

Dr. Beers served as an NBS consultant in atomic frequency and time standards for several months during 1960. In July of 1961 he was appointed Acting Chief of the Millimeter-Wave Research Section of the Radio Standards Laboratory; in October of 1961 he was appointed Chief of this Section.

Dr. Beers received his B.S. degree from Yale in 1934, and his M.A. and Ph.D. degrees in physics from Princeton in 1937 and 1941. For three years he was a member of the staff of the Radiation Laboratory at M.I.T., and for fifteen years Dr. Beers was a teacher at New York University, where he attained the rank of full professor. From 1947 to 1959 he was a consultant to the Brookhaven National Laboratories with the Atomic Energy Commission. In 1956 Dr. Beers worked as a Fulbright scholar with the Division of Electrotechnology of the Australian National Standards Laboratory and as visiting professor of the University of Sydney. He is the author of numerous papers in his fields; a book, "Introduction to the Theory of Error"; and chapters in the M.I.T. Radiation Laboratory Series.

Dr. Schafer joined the National Bureau of Standards in 1951. In 1955 he was appointed acting project leader of Microwave Attenuation Standards, and was appointed project leader the following year. In 1959 he became project leader of Microwave Attenuation Standards and Microwave Field Strength Standards. Before coming to NBS Dr. Schafer taught physics at Southern Methodist University and at Chadron State College. He has also taught courses and seminars at the Universities of Minnesota and Colorado and has served as a professor of electrical engi-

G. E. SCHAFER

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neering at North Carolina State College. Dr. Schafer received his B.A. degree in physics from Macalester College in 1943, his M.A. degree in physics from the University of Minnesota in 1949, and his Ph.D. degree from the University of Colorado in 1958.

While at the National Bureau of Standards, Dr. Schafer has improved existing standards of microwave attenuation, provided detailed instructions on the setting up of a calibration service for attenuators, originated a method of measuring the directivity of directional couplers which is presently being used by NBS, and made a basic study of microwave phase shift measurements which formed the basis for a new calibration service. His contributions have resulted in the publication of numerous scientific papers.

❖

The Polytechnic Institute of Brooklyn announced the appointment of **Dr. Mischa Schwartz** (S'46–A'49–M'54–SM'54), as acting head of the Department of Electrical Engineering.

Dr. Schwartz received his Bachelor's degree from Cooper Union in 1947, his Master's degree from Polytechnic in 1949, and his Ph.D. degree from Harvard in 1951.

He was formerly a project engineer with Sperry Gyroscope Co. Prior to this experience he taught physics at Cooper Union, lectured in the Graduate School at City College of New York, and worked as a radiation physicist at Montefiore Hospital.

Dr. Schwartz is a member of the American Society of Electrical Engineers, Tau Beta Pi, Sigma Xi and Eta Kappa Nu.

❖

Augustine R. Stratoti (S'54–M'59) has been named Chief Electrical Engineer for Gabriel Electronics, Millis, Mass.

A. R. Stratoti

Mr. Stratoti will be responsible for the activities of the Antenna Development Section in expanding and perfecting the Division's line of antenna system products.

A native of Brockton, Mass., Mr. Stratoti obtained both his Bachelor's degree and Master's degree in electrical engineering from Northeastern University in 1956 and 1958 respectively.

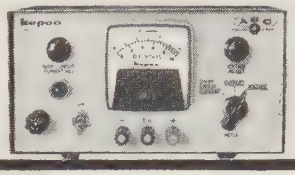
From 1953 to 1956 he was employed at Raytheon Manufacturing Co., Waltham, Mass. Until recently he was associated with Sylvania's Electronic Systems Division in Waltham where he served as an engineer and technical specialist in the areas of electromagnetic theory, antennas, and microwave systems.

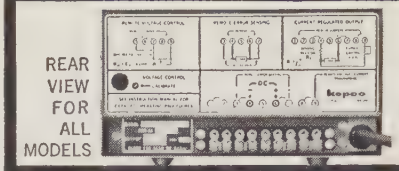
Mr. Stratoti is Chairman of Membership for the Boston Section of IRE, and Secretary-Treasurer of the local chapter of PGAP. Mr. Stratoti is a registered professional engineer in the state of Massachusetts.

❖

(Continued on page 66A)

KEPCO ABC REGULATED DC SUPPLY SERIES





A NEW KEPCO SERIES OF LOW COST VOLTAGE AND CURRENT REGULATED DC POWER SUPPLIES

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Model No.	DC Output Volts	DC Output Amps	Price
ABC 2-1M	0-2.0	1.0	$179.00
ABC 7.5-2M	0-7.5	2.0	$159.00
ABC 15-1M	0-15	1.0	$159.00
ABC 30-0.3M	0-30	0.3	$119.00
ABC 40-0.5M	0-40	0.5	$159.00
ABC 200M	0-200	0.1	$199.00
ABC 1500M	0-1500	0.005	$274.00

Prices listed include Volt-Amp meter. For unmetered units, delete suffix "M" from Model No. and deduct $20.00 from price.
Model ABC 1500M includes voltmeter only. For unmetered unit, delete suffix "M" and deduct $15.00 from price.

- 0.05% Line/Load Regulation and Stability
- 0.5 mv (rms) Ripple
- Adjustable Overload Protection (Front Panel)
- Input 105-125v ac, 50-440 cps
- Low Price is achieved by high volume production without sacrifice in quality and reliability.
- Control Amplifier Terminals included for:
  - Remote Constant Voltage Programming
  - Remote Constant Current Programming
  - Remote Error Sensing
  - Complementary Tracking
  - Voltage Compliance Extension
  - Slaved Tracking

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PRECISION TIME MEASUREMENT

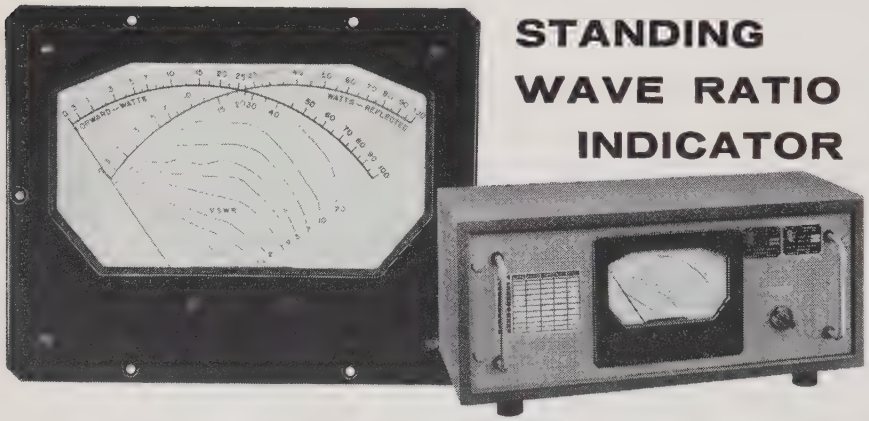
Interstate's Model 400 VLF Timing Receiver and Correlator is a highly-sensitive very-low-frequency receiver providing world-wide reception on switch-selectable frequencies of 16, 18, and 20 kc, and adaptable to other vlf channels. Completely solid-state . . . 2 kc i-f for optimum bandwidth . . . beat frequency or phase output. The Model 400 is a major component in the time and frequency synchronization systems produced by Interstate Electronics. Complete systems are available to meet your particular requirements for remote, millisecond, world-wide timing.

CONTACT MARKETING DEPARTMENT

Interstate ELECTRONICS CORPORATION
DEPT. 662, 707 E. VERMONT, ANAHEIM, CALIFORNIA
AREA CODE 714, PRospect 2-2222, TWX AH 5217
A SUBSIDIARY OF INTERSTATE ENGINEERING CORPORATION

SWR-3000

STANDING WAVE RATIO INDICATOR



The TMC Model SWR-3000 is a multi-purpose instrument which will instantaneously provide visual indications of Forward Power, Reflected Power, and Voltage Standing Wave Ratio.

The SWR-3000 may be used in any 50 or 70 ohm unbalanced transmission system covering 2-30 MCS, with average powers up to 3000 watts.

The SWR-3000 is used as an operational and maintenance tool at transmitter stations, in electronic plants for production testing of transmitters, and laboratories for RF transmission system measurements.

For additional information about the SWR-3000 and other test equipment, please contact TMC Test Equipment Division, Mamaroneck, New York.

The Test Equipment Division Of
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OTTAWA, CANADA • ALEXANDRIA, VIRGINIA • GARLAND, TEXAS • LA MESA, CALIFORNIA • POMPANO BEACH, FLORIDA

IRE People

(Continued from page 65A)

Lester G. Sturgill (M'52) recently joined the staff of the Jansky and Bailey Division of Atlantic Research, Alexandria, Va., as a specialist in antenna systems. Mr. Sturgill will work with the Division's Research and Engineering Department and, as a Principal Engineer, will be engaged in antenna work with emphasis on shipboard applications. He comes to Jansky and Bailey from Datronics Engineers, Inc., Bethesda, Md.

L. G. STURGILL

As the Director of Research and Development for Datronics Engineers, Inc., Mr. Sturgill directed a three-phase study program for the U. S. Navy.

Previous to joining Datronics Engineers, Inc. in 1960, Mr. Sturgill was Senior Engineer for Development Engineering Corp., Leesburg, Va. and was engaged in study and development of shipboard communications antenna systems.

From 1948 to 1958, Mr. Sturgill was with Crosley Broadcasting Corp., Dayton, Ohio. As Chief Engineer he directed a staff of engineers and technicians with responsibility for planning, installing, and operating the Company's television, FM stations, and intercity microwave system.

Mr. Sturgill received his B.S. degree in electrical engineering from the University of Cincinnati in 1949.

❖

Charles R. Vail (SM'57) has been appointed to serve on a newly formed Scientific Advisory Committee for the State of North Carolina.

The purpose of this committee will be to help in the implementation of the State's objectives in scientific and industrial development.

This Scientific Advisory Committee, consisting of approximately 40 representatives of all disciplines, was appointed in December, 1961.

❖

The appointment of **Robert A. Valley** (M'57) as Chief Engineer of Electronic Futures, Inc., New Haven, Conn. was announced recently. In this position he will direct the company's five-year engineering program to develop a series of new audio and visual products for language and programmed learning.

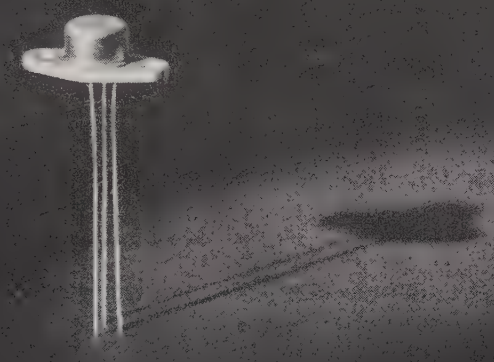
Mr. Valley received his engineering degree at the University of Connecticut, graduating in 1950. He served two years as a First Lieutenant in the U. S. Army Signal Corps.

He was formerly Manager of Military Engineering and assistant Director of Engineering for a company in the dictating and recording equipment field.

❖

(Continued on page 68A)

NEW SILICON TRANSISTORS FROM DELCO RADIO



ACTUAL SIZE

Silicon power transistors in a TO-37 package

Delco's unique new family of silicon NPN power transistors combines the benefits of miniaturization (TO-37) and light weight with the ability to withstand continuous junction temperatures of up to 175°C while operating at these absolute maximum ratings: collector diode voltage Vcb 100 volts; emitter diode voltage Vebo, 4 volts; collector current, 1 amp.; base current, .2 amp. This entire 2N2340 family is particularly useful where moderate power handling capabilities are required in a miniature package. The units have just two mounting holes and may be mounted with leads up, down or sideways on either side of the heat sink. Available in either single or matched units, they're characterized by low saturation voltage and high switching speeds. The transistors in this family are especially well suited for military or industrial applications in regulated power supplies, square wave oscillators, servo amplifiers and core driver circuitry. For complete engineering data, or applications assistance, write or call our nearest Sales Office or your nearest Delco Radio Semiconductor Distributor.

Number	IC Max.	Vcbo	Vceo	Sat. V @ IC Max.	Gain Min.—Max. @ IC	fae @ 250 ma IC (typical)
2N2340	1A	50V	40V	4V @ .75A	10— 40 @ .75A	900 kc
2N2341	1A	50V	40V	4V @ .75A	40—100 @ .75A	550 kc
2N2342	1A	100V	60V	3V @ .75A	10— 40 @ .75A	900 kc
2N2343	1A	100V	40V	2.5V @ .75A	40—100 @ .75A	550 kc

Thermal resistance of 8°C/watt max. Typical Alpha cutoff of 15 Mc

Rise Time of .2μ seconds—.75A, IB = 40 ma (Vce = 12V), Fall Time of .5μ seconds (IC = 0 Veb = 2v Reb = 37Ω)

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TRinity 3-6560
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UPton 0-8807
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Designed for M Application

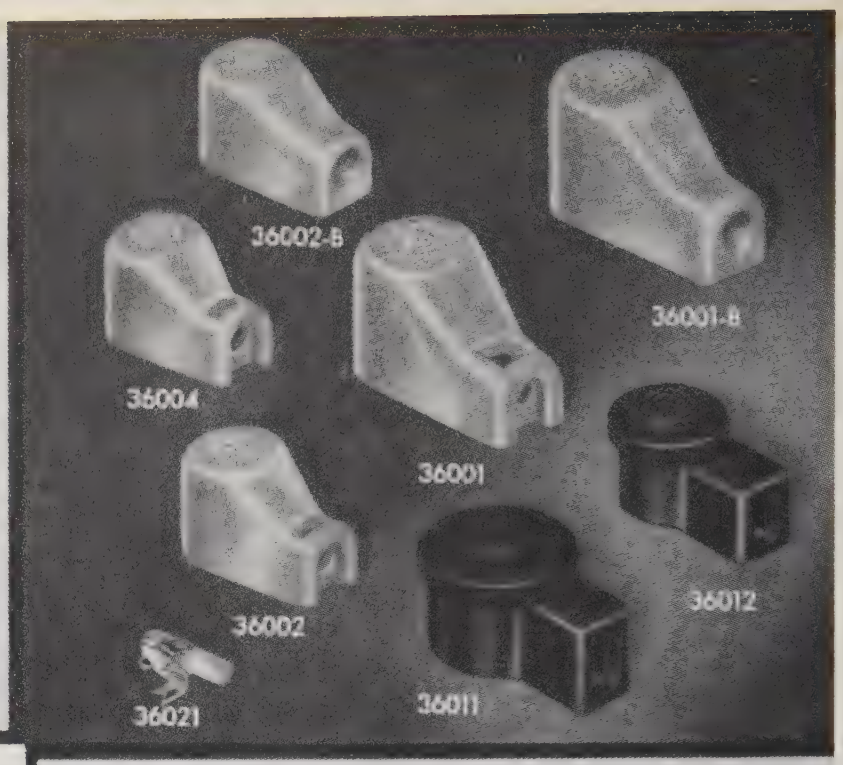

PLATE AND GRID CAPS

Illustrated are the stock military and standard ceramic Millen plate and grid caps and the snap lock caps for mobile and industrial applications requiring tighter than normal grip. Standard plate caps have phosphor bronze clips; military plate caps have beryllium copper clips.

JAMES MILLEN MFG. CO., INC.

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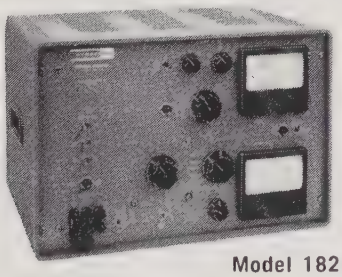
POWER TRANSISTORS - - - - - ONE KILOWATT pulsed testing - - - - - - - V_{CE} up to 300 VOLTS - - - I_C up to 100 AMPS



Model 1822

Power Transistor Test Set

Write for information about industry's most complete line of standard and custom designed instruments for semiconductor testing.

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electronics corporation

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IRE People

(Continued from page 66A)

Dr. John W. Clark (A'41–M'45–SM'58–F'61), Manager, Nucleonics Division, Hughes Aircraft Company Ground Systems Group, has been elected to membership in the New York Academy of Sciences in recognition of outstanding achievement in the field of physical sciences.

J. W. Clark

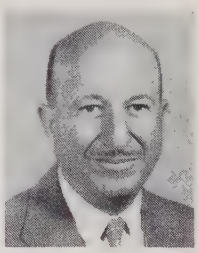
Since joining Hughes Aircraft Company in December, 1955, Dr. Clark has been responsible for the development of scientific programs applying nuclear technology within the context of a large electronics system research and development organization. Some of his specific scientific achievements were the early recognition of the serious effects of transient nuclear radiation and the initiation of a research program in this new field of technology; the development of high power linear accelerators as research tools for transient effects investigations; and the analysis of a variety of nuclear radiation problems associated with the nuclear aircraft program. This work in turn led to the development of novel concepts for electronic remote handling systems for use in nuclear laboratories.

Dr. Clark received his B.A. degree in physics and mathematics from Montana State University in 1935 and his Ph.D. degree in physics from the University of Illinois four years later.

Dr. Clark is a member of the American Association for the Advancement of Science, the American Nuclear Society, the American Physical Society, the American Rocket Society, and Sigma Xi.

❖

John H. Homsy (SM'47) recently retired after more than thirty-two years in the Federal Civil Service. At the time of his retirement, Mr. Homsy was Deputy Scientific Advisor of the Field Test Directorate, U. S. Army Electronic Proving Ground, Fort Huachuca, Ariz.

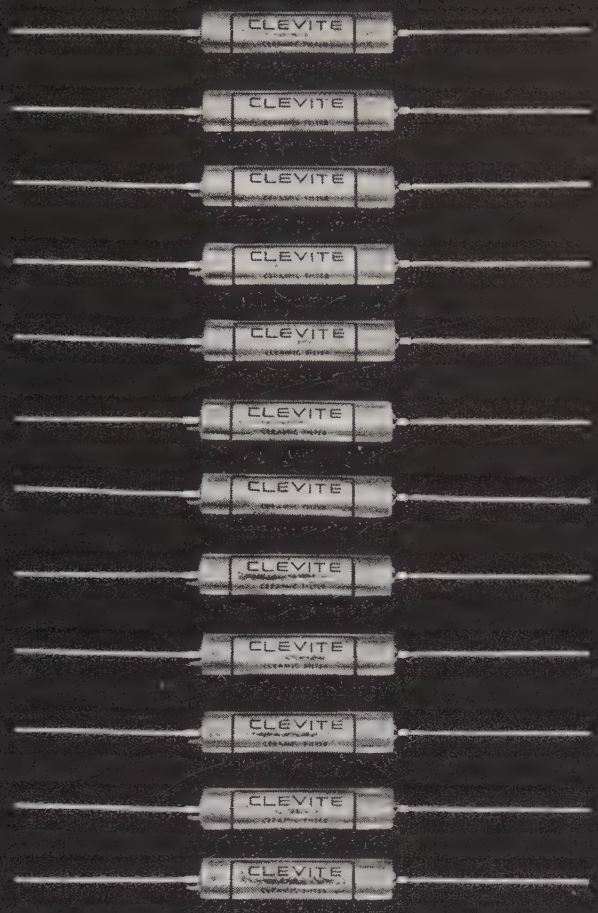


J. H. Homsy

Before coming to Fort Huachuca in 1955, Mr. Homsy was for nine years Engineer-in-Charge at Dallas, Tex., for the Federal Communications Commission. He had previously served with the Department of Commerce and the Federal Radio Commission.

Mr. Homsy is past Chairman of both the Dallas-Fort Worth and Fort Huachuca

(Continued on page 70A)



MODEL	6db BANDWIDTH
TL-2D5A	2 kc
TL-4D9A	4 kc
TL-6D12A	6 kc
TL-8D16A	8 kc
TL-10D18A	10 kc
TL-16D25A	16 kc
TL-20D32A	20 kc
TL-30D45A	30 kc
TL-40D55A	40 kc
TL-45D60A	45 kc
TL-32E48C	32 kc
TL-50D85C	50 kc

(suffix "A" denotes 455 kc center frequency;
suffix "C" denotes 500 kc center frequency)

Clevite Ceramic Ladder Filters

Now in stock in 12 bandwidths... 80 db rejection in 0.1 cu. in.

Clevite ceramic ladder filters provide more selectivity for their size than any conventional i-f filter. They are fixed tuned and need no alignment—are non-magnetic and non-microphonic. Leading manufacturers now have Clevite ladder filters in their communications equipment. Improve your newest design with these unique filters. Write now for complete specifications—Bulletin 94012, or for selectivity curves available on each stock model. ■ Dimensions: 5/16" diameter x 1½" long. ■ Selectivity: 60 db/6db shape factor from 1.3:1 to 2.6:1. ■ Center Frequency Stability: within 0.2% for 5 years, and within 0.2% from −40° to +85° C. ■ Impedance: 1200-1500 ohms. ■ Designed for military environment.

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PS-60 DIGITAL POWER SUPPLY

Condensed Specifications:

Outputs			
Voltage	Icont. (max)	Isurge (max)	Regulation
—10 v	3 amp	6 amp.	2% (Surge)
—45 v	1 amp	60 amp.	2% (Surge)
Surge current pulse duration 1 ms, repetition rate 12 c-p-s			
10 v	100 ma. to 1 amp		1%

Vibration: MIL-STD-167
Shock: 50 g. per MIL-STD-202
Size: 4.8 x 2.92 x 17.35 inches, 10½ lbs.

YOUR SPECIFICATIONS BRING AN IMMEDIATE QUOTE

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SIE DIVISION / A DIVISION OF DRESSER INDUSTRIES, INC
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IRE People

(Continued from page 68A)

Sections of the IRE. He is also a member of Eta Kappa Nu.

In 1955 he was an electronic engineer in the Engineering and Technical Department of the Fort Huachuca Proving Ground and after one year he became Technical Director of what is now the Electronic Environmental Test Facility.

Mr. Homsy received a B.S. degree at the University of California in 1928. He worked with a public utilities concern for a year before entering the Federal service. For the following ten years he worked in California as Field Engineer for the Department of Commerce, the FRC and the FCC.

❖

Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., announced the appointment of **H. C. Tittle** (A'27–M'55) as Vice President and General Manager of the central operation in Buffalo, N. Y.

H. C. Tittle

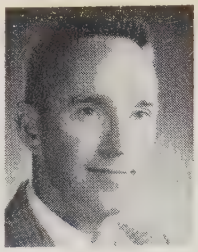
Mr. Tittle has been connected with the Sylvania organization for more than twenty-five years. He joined the Colonial Radio Corporation as Chief Engineer in 1935.

In 1948 he became Chief Engineer of the then Home Set Division, and two years later was named Assistant Chief Engineer for the then Radio and Television Division. In 1952, he became Manager of the Boston Engineering Laboratories and in 1955 was appointed General Manager of the central operation in Buffalo.

Mr. Tittle holds B.S. and E.E. degrees from South Dakota State School of Mines and Technology.

❖

Hughes Aircraft Company recently announced the appointment of **John W. Black** (M'60) as Vice President and Manager of the Aeronautical Systems Division, Aerospace Group.



J. W. Black

Mr. Black has been employed by Hughes Aircraft since 1940, most recently as Manager of Aeronautical Systems Division, before that as Manager of the Tucson, Ariz. Division. He was graduated from California Institute of Technology with a B.S. degree in mechanical engineering. He is a member of the Research Engineering Society of America.

❖

New management assignments for **Dr. Alan D. Sutherland** (M'53) and **James A. Noland** (M'56) were recently revealed at Sperry Electronic Tube Division, Gainesville, Fla.

A. D. Sutherland

J. A. Noland

Dr. Sutherland has been appointed Engineering Manager, Research, and Mr. Nolan has been named Engineering Manager, Advanced Development.

Dr. Sutherland, who has been associated with Sperry since 1956, has engaged in research programs concerning ion plasma interaction with electron beams, and space-charge instabilities in electron beams. He has also performed research on the multi-pactor phenomena in klystrons, periodic electrostatic focusing, and space-charge wave interation in periodic dc fields.

Sutherland holds a Ph.D. degree awarded by the University of Illinois, and he has written many technical papers. He is a member of the IRE Professional

(Continued on page 72A)

For Printing or Color-banding of Electronic Components:

REJAFIX MARKING MACHINES

in fifty different models

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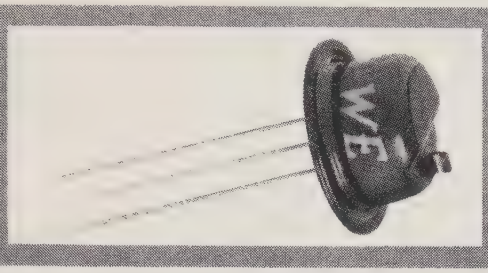
300 Park Ave. South, New York 10, N.Y.

HIGH CURRENT SWITCHING TRANSISTOR 2N1072

TO-38 PKG.



1½ times actual size

12.5 WATTS, 75 VOLTS, 2 AMPERES

Western Electric's 2N1072 is an NPN diffused silicon mesa transistor, designed by Bell Telephone Laboratories for high current switching and core driver applications. Typical turn-on time is 80 nanoseconds. Typical turn-off time is 200 nanoseconds. One ampere may be switched at rise and fall times of 50 nanoseconds. The maximum power dissipation at a case temperature of 100°C is 5 W.

ABSOLUTE MAXIMUM RATINGS (T_C=25°C)

P_C	V_{CES}	V_{EBO}	V_{CBO}	I_C &-I_E
12.5 W	75 Vdc	6.0 Vdc	75 Vdc	2.0 A

ELECTRICAL CHARACTERISTICS

	h_{FE}	V_{CE} (sat)	V_{BE} (sat)	$t_d + t_r$	$t_s + t_f$
	(V_{CE}=5 Vdc)	(I_C=750 mAdc)	(I_C=750 mAdc)	(V_{CC}=20 Vdc)	(R_C=25 ohms)
	(I_C=750 mAdc)	(I_B=75 mAdc)	(I_B=75 mAdc)	($I_{B\,(1)}$=75 ma)	
				($V_{BE(0)}$=0)	($I_{B(2)}$=−75 ma)
Min.	20	—	0.70 Vdc	—	—
Max.	—	2.0 Vdc	1.8 Vdc	100 nsec	300 nsec

The 2N1072 transistor may be purchased in quantity from Western Electric's Laureldale Plant. For technical information, price, and delivery, address your request to Sales Department, Room 106, Western Electric Company, Incorporated, Laureldale, Pa. Telephone — Area Code 215 — 929-5811.

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INSTITUTE OF RADIO ENGINEERS, INC.
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IRE People

(Continued from page 70A)

Group on Electron Devices and the Professional Group on Microwave Theory and Techniques.

Mr. Noland joined Sperry Electronic Tube Division in 1961. Since joining the division, he has been concerned with the development of backward wave oscillators and two-cavity klystron oscillators.

Noland earned his Master's degree in physics from Purdue University. He is a member of the IRE Professional Group on Electron Devices, the American Physics Society, and Sigma Xi.

❖

New appointments for four managers of Raytheon Company's Microwave and Power Tube Division have been announced.

Bertram G. Ryland (A'44–M'47) has been named Consultant, Microwave Devices. The new Manager of Engineering for the division is **Dr. Howard Scharfman** (S'47–A'50–M'55–SM'61). **Dr. Colin Bowness** (M'57) will take Scharfman's former post as Manager of the division's Special Microwave Devices Operation. **William C. Brown** (A'39–M'55–SM'58–F'59) has been named Manager, Super-Power Programs.

Mr. Ryland joined Raytheon in 1959 as Director of Engineering for the division. Earlier, he had been with the General Electric Co., for eight years, serving last as High Power Klystron Manager at their laboratory in Palo Alto, Calif., and with the Stanford Electronics Research Laboratory. He earned his B.S., M.S., and Engineer degrees from Stanford University. Mr. Ryland is a member of Sigma Xi and the Joint Electronic Devices Engineering Council.

Dr. Scharfman joined Raytheon in 1954, serving first as Head of the Microwave Ferrite Section, then was named Manager of the company's new Special Microwave Devices Operation in 1957. Earlier, he had been with the Boeing Airplane Co. and taught electrical engineering at Brooklyn's Polytechnic Institute. He holds a Bachelor's degree from New York University, a Master's degree from Northwestern, and a Doctorate of Science from Johns Hopkins University. He is a member of Eta Kappa Nu and Sigma Xi.

Dr. Bowness was most recently Manager of Engineering for the Special Microwave Devices Operation and has held several engineering and research positions of increasing importance since joining the company in 1957. Earlier, he had done research and development with the Microwave Laboratory of the Electrical and Musical Industries, Seltham, England. He holds a B.S. degree in physics and a Ph.D. degree from the University of London.

Mr. Brown pioneered in the development of the high powered tube for radar systems known as the Amplitron. He received the Naval Ordnance Development Award in 1945, and a Certificate of Com-

(Continued on page 74A)

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From Europe's centres of electronics research and development —universities, industries, government agencies—comes a prolific stream of new ideas and practical applications.

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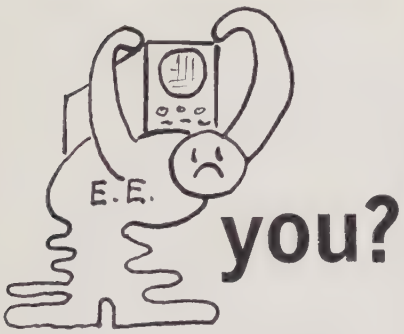

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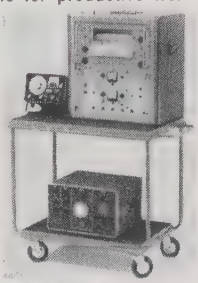

Many other models!

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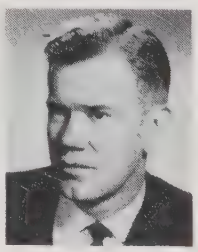
IRE People

(Continued from page 72A)

mendation in 1947, for outstanding work on vital wartime military projects. He holds a B.S. degree from Iowa State College and a M.S. degree from MIT. With Raytheon since 1940, he served most recently as Associate Director of Engineering.

❖

The election of **Robert L. Jannen** (A'60) to the office of Vice President in Charge of Sales for Leach Corporation has been announced.



R. L. JANNEN

Mr. Jannen is a graduate of the U. S. Maritime Academy, Tri-State College, and UCLA in engineering and business administration. He completed additional courses in marketing at Pasadena City College, public speaking at the Mullin School, and language courses at Berlitz.

The new Vice President in previous capacities at Leach as Director of Marketing and Assistant Vice President directed the foundation of a nationwide centralized sales organization.

Mr. Jannen is the author of numerous papers and articles on electronic distribution widely printed as authoritative by technical publications throughout the U. S. He is a member of the Sales Executive Club, American Management Association, American Marketing Association, American Rocket Society, and is listed in "Who's Who in Commerce and Industry."

❖

The National Academy of Sciences recently awarded its John J. Carty Medal to **Dr. Charles H. Townes** (SM'58) in recognition of his pioneering work in the development of the maser. The medal was established in order to recognize noteworthy and distinguished accomplishments in any field of science coming within the scope and charter of the Academy.

Dr. Townes was graduated from Furman University in 1935 with Baccalaureate degrees in physics and modern languages. He received his Master's degree in physics from Duke University in 1937, and his Doctoral degree, also in physics, from the California Institute of Technology.

A member of the technical staff of Bell Telephone Laboratories from 1939 to 1947, Dr. Townes worked extensively during World War II in designing radar bombing systems. He then directed his attention to the field of microwave spectroscopy, which grew out of wartime radar research and which he foresaw as a new analytical tool for the study of atoms and molecules.

(Continued on page 76A)

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Provides increased edge periphery of the emitter for desirable current rating with decreased junction area for good high frequency characteristics.

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Provides higher frequency response, lower total control charge, and at the same time, lower saturation voltage and collector capacitance.

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Protects against junction contamination during manufacture and provides long-term stability . . . ensures more uniform gain at low and high currents by passivating the surface through the planar process.

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2N2218

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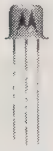
2N2222



Since the introduction of Motorola's silicon epitaxial Star planar transistor series, many users have commented on its performance. One firm is using this new transistor ". . . because of its outstanding gain at only 2.5 uA."

Another company reports the highest gain at high current levels of any type previously tried. Both firms noted the Star planar's unusually high frequency response.

To still another manufacturer the broad-range performance of the Star transistor has meant being able to reduce the number of different devices required to their equipment from 7 types to 1 type.

For your new circuit designs you can plug in "performance" previously unavailable in any device at any price. And these new Motorola units are priced competitively with older devices . . . as low as $3.90 each in quantity.

See for yourself what a Motorola Star planar will do in your circuit designs. If you have a bona fide application for any of these remarkable new transistors, contact your nearest Motorola District Office. A sales engineer will advise you how you may obtain free samples.

TO-5 Package (P_D = 0.8 watts) / TO-18 Package (P_D = 0.5 watts)	2N2217 / 2N2220	2N2218 / 2N2221	2N2219 / 2N2222
h_{FE} @ I_C = 150 mA	20-60	40-120	100-300
$V_{CE(sat)}$ volts (max) I_B = 500 mA I_B = 50 mA	--	1.6	1.6
C_{ob} I_E = 0, V_{CB} = 10 V	8 picofarads (maximum)—All Types		
f_T I_C = 20 mA, V_{CE} = 20 V	250 mc (minimum)—All Types		
Switching Time (total) non-saturated	12 nsec (typical)—All Types		
Switching Time saturated t_{on} / t_{off}	26 nsec (typical)—All Types 68 nsec (typical)—All Types		

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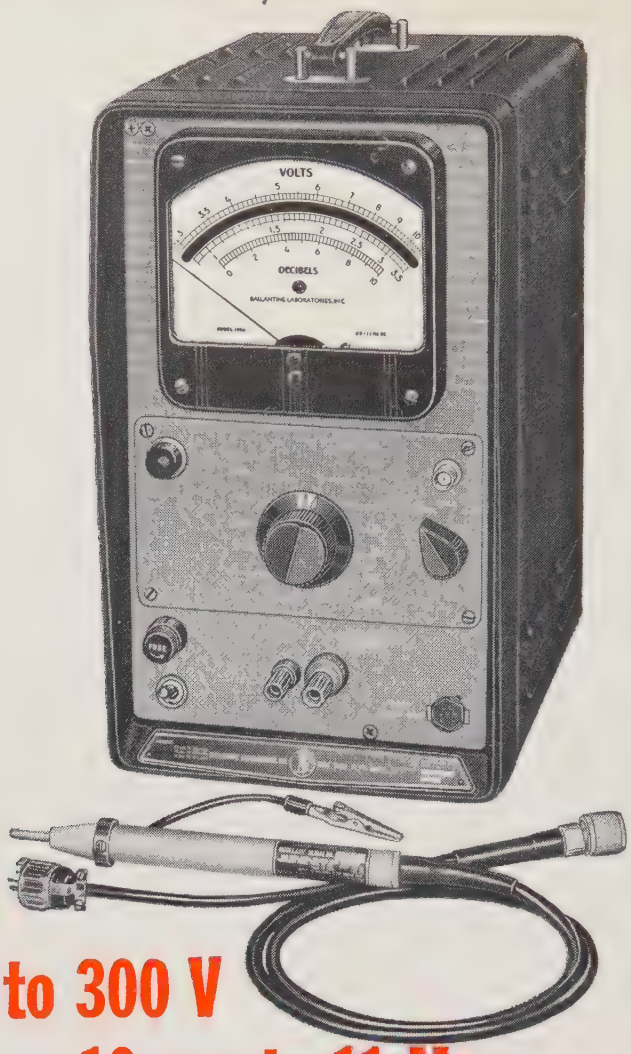

Measures 300 μV to 300 V

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A stable, multi-loop feedback amplifier with as much as 50 db feedback, and 10,000 hour frame grid instrument tubes operated conservatively, aid in keeping the Model 317 within the specified accuracy limits over a long life. A million to one in voltage range and over a million to one in frequency coverage makes it attractive as a general purpose instrument for measurement of af or rf as well as the complete band. **All readings have the same high accuracy over the entire five inch voltage scales.** This is typical of all Ballantine voltmeters due to the use of individually calibrated logarithmic scales.

The 317 may be used as a null detector from 5 cps to 30 Mc having a sensitivity of approximately 100 μV from 10 cps to 20 Mc.

SPECIFICATIONS:

VOLTAGE: 300 μV to 300 V.
FREQUENCY: 10 cps to 11 Mc (As a null detector, 5 cps to 30 Mc).

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SCALES: Voltage, 1 to 3 and 3 to 10, each with 10% overlap. 0 to 10 db scale.

INPUT IMPEDANCE: With probe, 10 megohms shunted by 7 pF. Less probe, 2 megohms shunted by 11 pF to 24 pF.

AMPLIFIER: Gain of 60 db ± 1 db from 6 cps to 11 Mc; output 2.5 volts.

POWER SUPPLY: 115/230 V, 50 — 400 cps, 70 watts.

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IRE People

(Continued from page 74A)

Dr. Townes joined the Columbia faculty as Associate Professor of Physics in 1948, was appointed Professor in 1950, and served as Executive Director of the Columbia Radiation Laboratory from 1950 to 1952 and as Chairman of the Physics Department from 1952 to 1955. He went abroad in 1955 and 1956 as a Fulbright Lecturer, first at the University of Paris and then at the University of Tokyo.

In 1959, while on leave of absence from Columbia, Dr. Townes became Vice President and Director of Research for the Institute for Defense Analyses, Washington, D. C., which position he held until his appointment as MIT Provost.

❖

Dr. Zvi Prihar (SM'51) has been appointed Scientific Advisor to the Director of Research and Development at Page Communications Engineers, Inc., Washington, D. C.

Z. PRIHAR

Dr. Prihar has more than thirty years of experience in communications-electronics and operations research applications. With the Iraq Petroleum Company, he planned and directed extensive pipeline communications systems throughout the Middle East and was advisor to several Middle East government telecommunication administrations. On creation of the new state of Israel, he was invited to assume the post of Director General, Postmaster General. In this office, he planned and established the national postal, telephone, telegraph, radio, and international communication services.

He was also with RCA as Administrator of Special Studies-Communications and Consulting Engineer, and has been Professor of Electrical Engineering at two universities.

Dr. Prihar received his Doctor of Engineering Science degree from Columbia University, and Ing.Dipl. degree in electromechanical engineering from the University of Caen, France. He is a Registered Professional Engineer, and a Member of the Operations Research Society of America.

❖

J. Wesley Leas (M'45–SM'51) has been selected General Chairman of the Fall Joint Computer Conference to be held December 4–6, 1962, at the Sheraton Hotel, Philadelphia, Pa.

Mr. Leas is Chief Engineer, Electronic Data Processing, for the Radio Corporation of America, and acts as an advisor to an agency in the Department of Defense. In 1955 he served on the Four Member

Advisory Group on Computers for the Assistant Secretary of Defense, Research and Development.

Joining RCA in June 1951, Mr. Leas has played an important role in the development of RCA's data processing activities and was appointed to his present position as Chief Engineer in December 1961. He is a member of Eta Kappa Nu, the Association for Computing Machinery, and the Armed Forces Communication and Electronics Association.

In addition to his work with electronic computers, Mr. Leas has made notable contributions to the field of aircraft radar and traffic control. Following military service he was appointed Airborne Radar Chief of the Airborne Instruments Laboratory which included flight testing of airborne radar for commercial airlines' use. In 1949, he joined the Air Navigation Development Board.

❖

The appointment of **Allan Karson** (M'57) as Vice President in charge of the Data Systems Division of The G. C. Dewey Corp., New York, N. Y. was announced.

In his new post, Mr. Karson will supervise operations analyses and design of computer-communications systems. He will also direct the firm's newly-organized mathematics group, in support of analyses in information theory.

He has been Senior Associate of the Dewey Corp. in charge of computer programming and computer-communications systems since 1959. He joined the company as a technical staff member in January 1957, and has performed detailed studies in real-time problems involved in air defense and in the SAC control system.

Before joining the Dewey Corp. Mr. Karson had been Design Engineer at the Aberdeen Ballistics Research Labs., and a design engineer for the EDO Corp.

A graduate of the College of the City of New York with a B.S. degree in electrical engineering, Mr. Karson earned a M.S. degree in electrical engineering at Columbia University in 1956. He is a member of Tau Beta Pi and Eta Kappa Nu.

❖

Rodolfo M. Soria (S'38–A'43–M'46–SM'49–F'58), Vice President, Research and Engineering, Amphenol-Borg Electronics Corp., Broadview, Ill., has been elected a director of the Company.

Mr. Soria was graduated from Massachusetts Institute of Technology and Illinois Institute of Technology, where he received his B.S. and Ph.D. degrees in electrical engineering in 1939 and 1947 respectively.

Mr. Soria has served as a consultant to the Department of Defense, Office of Defense Research and Engineering.

❖

Leroy Packer (S'48–A'51–M'56) was recently named President of Intercontinental Instruments Incorp. (31), Farmingdale, N. Y. His new responsibilities will

(Continued on page 78A)

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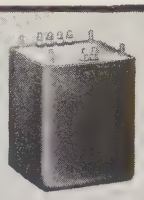

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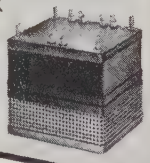

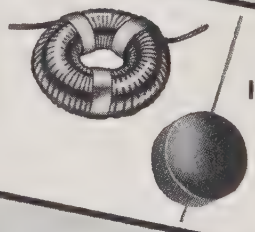

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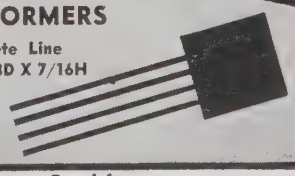

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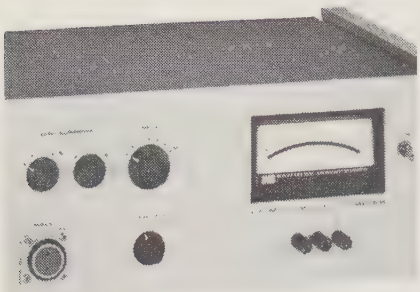

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Zero suppression up to 100 times full scale adds versatility for the user. Line-operated, the Model 149 can accommodate either a floating or ground-referenced input. Output is 5 v or 5 ma on all ranges. Brief specifications:

- **range:** 0.1 microvolt to 100 millivolts in 13 overlapping 1x and 3x steps.
- **noise:** less than 6 x 10^{-10} v rms with shorted input.
- **input impedance:** 10K ohms on 0.1 μv range rising to 10 megohms on 100 μv scale.
- **stability:** within 0.01 μv per hour.
- **speed of response:** to 90% fs in .5 seconds on most ranges.
- **accuracy:** 2% fs on all ranges.
- **price:** $895.00

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Model 150A	1 μv sensitivity	$750.00
Model 151	100 μv sensitivity	$420.00

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IRE People

(Continued from page 77A)

involve direction of development and manufacturing efforts in the data processing, spectrum analysis, microwave and pulse generation areas in government contract and commercial fields.

Mr. Packer was formerly associated with General Applied Science Labs. where, as Director of their Electronics Division, he supervised technical and administrative endeavors in specialized technical areas. Previously, Mr. Packer was Head of General Engineering for Polarad Electronics Corp., with responsibility for all systems work, as well as for the supervision of their Circuits, Computer and Analysis Groups. Additionally, he directed research work on navigational and guidance systems while a group leader and staff member of the Columbia University Electronics Research Lab. He was a section head at the Research Division of the Burroughs Adding Machine Co., and an Engineering Staff member of the Franklin Institute Research Labs.

An electrical engineering graduate of Columbia University and the Moore School of the University of Pennsylvania, Mr. Packer is the author of numerous papers on computing devices and special test equipment concerned with spectrum analysis and correlation techniques. He is a member of Tau Beta Pi, the Professional Group on Electronic Computers, and the Professional Group on Information Theory.

❖

Carl Richardson (SM'61) has been appointed Chief Engineer for Baird-Atomic, Inc., Cambridge, Mass. In his new position he will be responsible for commercial instrument development engineering, and production.

Mr. Richardson joined Baird-Atomic, Inc. in 1952, and since that time has held a number of technical positions, becoming Assistant Director of Research in 1956. While at Baird-Atomic, Inc. he has participated directly in the design and development of a number of electronic systems including an automatic optical tracker, transistor test equipment, liquid scintillation spectrometer, and high density packaging techniques.

Mr. Richardson is a graduate of Northeastern University, and has performed graduate studies at Harvard University, in semiconductor and solid state physics.

❖

Richard W. Hanford (SM'53) has been elected Vice President and Technical Director of White Electromagnetics, Incorp., Bethesda, Md.

Mr. Hanford formerly was a member of the Technical Staff of Advanced Military Systems, Radio Corporation of America,

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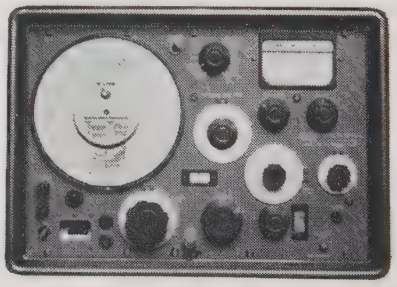

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Main Plant: St. Albans, England

which was responsible for planning and control of all RCA defense operating divisions.

He brings to White Electromagnetics more than eighteen years of professional scientific background, including both industrial and university experience. He has authored and presented numerous papers, and is a member of several professional and honorary societies.

❖

The election of **Melvin B. Kline** (A'43–M'44–SM'48) as Vice President, Research and Development of American Avionics, Inc., Los Angeles, Calif., was announced.

In previous associations, Mr. Kline was Director of Research and Development for the Electronic Systems Division of Telecomputing Corp. Prior to that he was with the Allen B. DuMont Labs., Inc. where he established and managed the west coast division which was primarily concerned with guided missile test and checkout.

He is well known for his activities in radar countermeasures, air traffic control, and electronic test and checkout equipment. Mr. Kline has been responsible for the design and development of many existing military equipments. He holds a number of patents including inventions covering cathode-ray indicator circuitry and a wideband continuously-variable precision delay line.

Mr. Kline received his B.S. degree in Physics from the College of the City of New York, his M.S. degree in electrical engineering from Stevens Institute of Technology, and his Master's degree from UCLA in engineering. At the present time he is engaged in further graduate work towards his Ph.D. degree. He is also active in the UCLA engineering teaching staff.

He is a senior member of the American Rocket Society and a member of the American Management Association.

❖

Dr. H. Gunther Rudenberg (S'41–A'45–M'51–SM'57) has joined Arthur D. Little, Inc., Cambridge, Mass., as a member of the Senior Staff of the Research and Development Division. In this post Dr. Rudenberg will be concerned with the development of the new generation semi-conductor devices, and related research and engineering problems.

H. G. RUDENBERG

Previously Dr. Rudenberg was Director of Research at Transitron Electronic Corp. a post he held since the founding of the firm in 1952. Most recently he was engaged in microminiature and thin-film device research. Dr. Rudenberg holds a Ph.D. degree in physics from Harvard University. Active in IRE affairs he is 1962 Chairman of the Northeast Electronic Research and Engineering Meeting.

❖

(Continued on page 80A)

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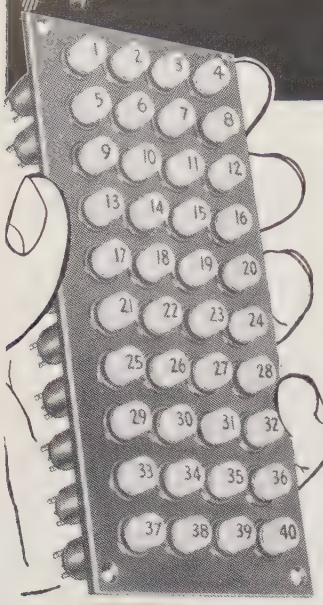

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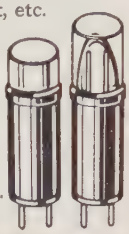

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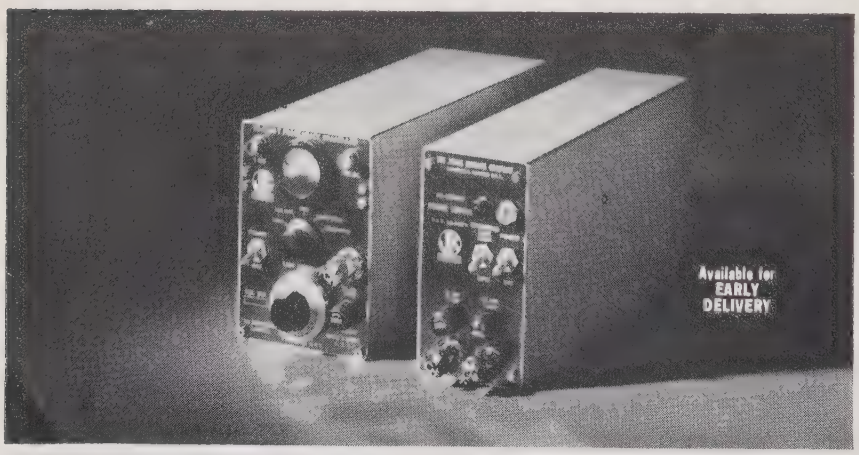

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IRE People

(Continued from page 79A)

Bernard S. Landman (S'61–M'62) has joined Potter Instrument Company, Inc., Plainview, L. I., as Project Engineer for the Systems Department. He will work on special Potter high density recording equipment, and is presently working on Potter's G-20 Computer project.

Mr. Landman comes to Potter from PRD Electronics, Inc., Brooklyn, N. Y. He received his B.S. degree in electrical engineering, cum laude, from the College of the City of New York and has completed required courses for his Master's degree in electrical engineering at the Polytechnic Institute of Brooklyn, N. Y.

He is a member of the Armed Forces Communications and Electronics Association.

❖

Roger A. La Plante (A'52–M'56) has joined S-F-D Laboratories, Inc., Union, N. J., as Sales Manager. He will be directly responsible for sales and marketing of S-F-D's CEM and ICEM Coaxial Magnetrons and its new crossed-field amplifiers.

R. A. La Plante

Mr. La Plante joins S-F-D from Amperex Electronic Corp., Hicksville, N. Y., where he was Products Manager-Microwave Devices. Prior to becoming Products Manager, he directed a staff of engineers in the development of klystrons and tunable magnetrons in *S*- and *X*-band, and in the use of impregnated cathodes. He was formerly associated with Philips Laboratories, Irvington, N. Y. where he was involved in experimentation with *X*-band, two-cavity klystron oscillators and the design of tube structures, process schedules and test equipment.

Mr. La Plante has had several articles published on the reduction and measurement of microphonics in klystrons. He served on the IRE's Standards Subcommittee on Measurements of Microwave Oscillators, and was Secretary-Treasurer and Vice-Chairman of the Westchester, New York Subsection.

Mr. La Plante received his B.E.E. degree from Rensselaer Polytechnic Institute in 1951.

❖

Dr. Paul Keck (M'57) has joined the Central Research and Engineering staff of Texas Instruments Incorporated to direct programs in new technologies. His major responsibility will be to direct research and development in lasers in TI's Central Research Labs. Dr. Keck pioneered the floating zone technique of materials purification and its application to silicon. He has had many scientific papers published, holds patents in the fields of optics and crystal

chemistry, and has been widely recognized for his analyses of semiconductor solids.

Prior to joining TI, Dr. Keck was with the General Telephone Research Labs. Previously he was associated with the U. S. Signal Corps Labs. For many years an optical expert with the Zeiss Company in Germany, he also taught at the University of Munich.

Dr. Keck received his Doctoral in physics at the Institute of Technology, Munich, and his Doctoral in optics at the University of Jena.

❖

It was recently announced that **General Don Flickinger** (A'61), former Director of Life Sciences for the United States Air Force, will work with the Instrument Division of Lear, Incorporated, Grand Rapids, Mich., as a consultant in the field of man-machine problems. He will serve as Bio-Medical Adviser to the Grand Rapids firm.

Prior to his retirement, General Flickinger was a prime participant in the development and establishment of criteria for selection of the Mercury astronauts. He served as Assistant to the Commander, Air Research and Development Command, for bioastronautics; as Command Surgeon and Director of Human Factors for the Air Research and Development Command; and as Commander of the Air Force's Office of Scientific Research.

A medical graduate of Stanford University, General Flickinger is a member of the American Medical Association; a Fellow of the Aerospace Medical Association and the College of Physicians; and specializes in the fields of physiological aspects of aerospace flight, physchological disorders of aerospace flight, and bio-engineering problems of aerospace flight.

❖

James H. Green (SM'61) has been appointed Director, Telecommunications System at Page Communications Engineers, Inc., Washington, D. C.

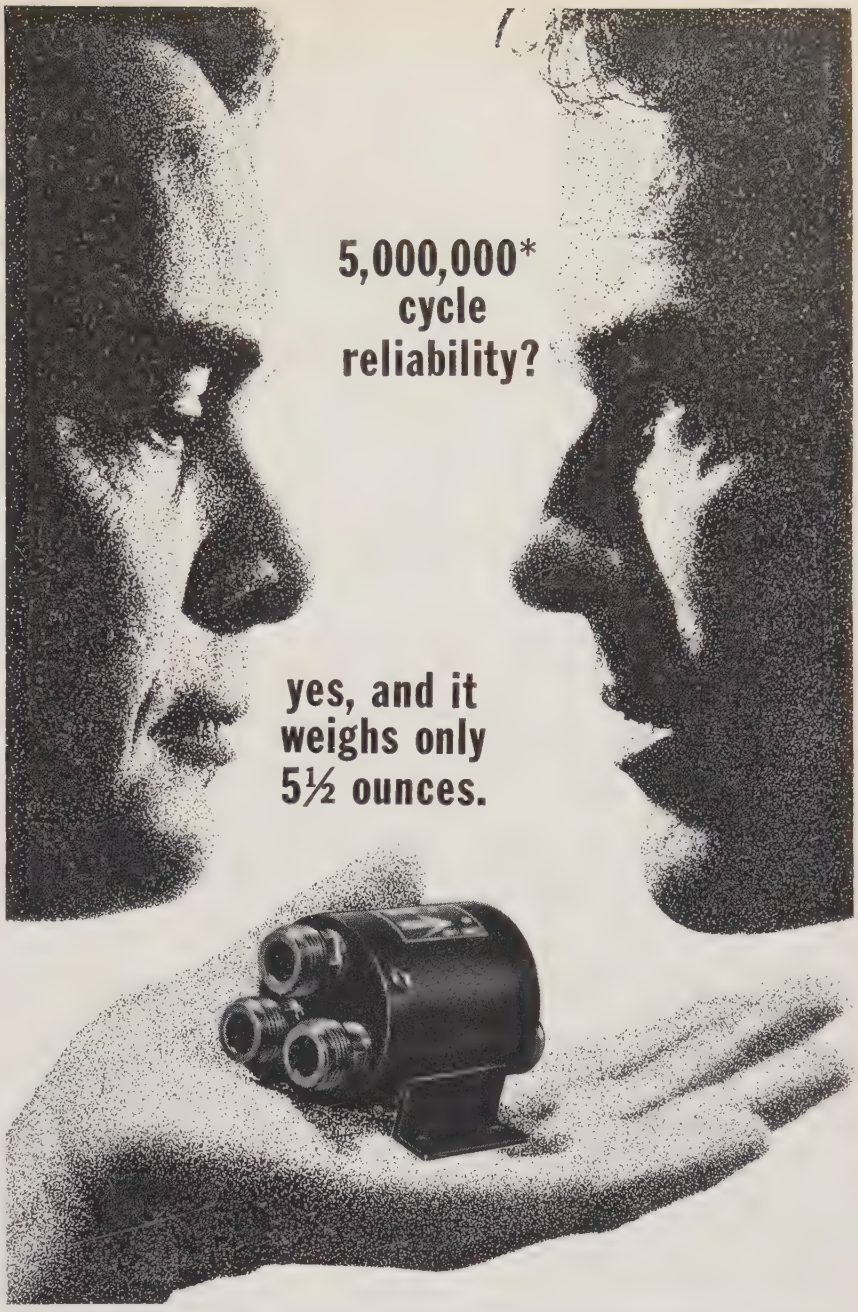
J. H. GREEN

Mr. Green was formerly Director of the Space Communication Division of Alpha Corp. With twenty years of experience in electronics, he is an authority in the systems design, procurement, fabrication, and test of space-communications stations designed to provide communication with satellites and deep space probes.

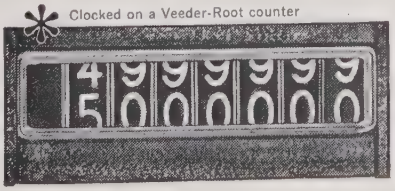
He has directed experimentation and development of stations, for communication by means of passive and active satellite repeaters. He has also served as Technical Program Manager on communications-systems development for the Navy's Polaris, as Program Planner for the Rascal program, and as Radio and Radar Officer in the U. S. Army Signal Corps.

Mr. Green received his B.S. degree in

(Continued on page 82A)



Here's still another new coaxial switch design from Transco. It's a small, lightweight, 50-ohm Type K coax switch, reliable even after a full 5,000,000 cycles! Two Transco built-in features add to this long life: unique self-cleaning wiping contacts, and dual solenoids, which permit fail-safe operation. ■ Solenoid voltage is 28 VDC; connector types are N, BNC, TNC, and BSM. MIL approved, its RF characteristics are excellent to 4 GC. Typical specs at 2 GC: VSWR 1.2, insertion loss 0.25 db, crosstalk 40 db. For complete details, write to Transco Products, Inc., 4241 Glencoe Avenue, Venice, Calif.



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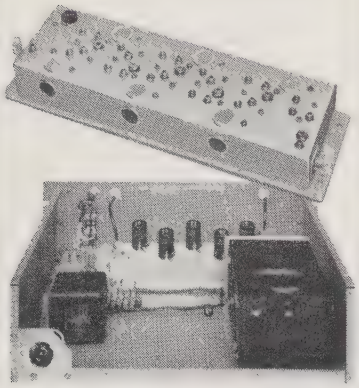

LEL's new line of Octave Amplifiers reflects the same outstanding design and quality manufacturing techniques that have made LEL the "reliability" leader in Microwave System Components.

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The New Octave Amplifiers are available as self-contained mounted units, including solid state regulated power supplies, or as amplifiers only.

Featuring:
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- Greater Dynamic Range
- VSWR: 1.5-1.7
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IRE People

(Continued from page 81A)

physics from Yale University and holds basic patents in the field of correlation communication.

❖

The appointment of **Alcibiades Claudio** (A'61) as Manager Director of EMEC, INC., Plainview, N. Y., was announced. Mr. Claudio has been affiliated with Electronic Export Organizations for twenty years. In various capacities he has travelled extensively throughout Latin America and the Orient.

A. Claudio

Mr. Claudio, born in Puerto Rico, earned his B.S.S. degree at the College of the City of New York and his M.A. degree at Columbia University. He was a candidate for his Ph.D. degree at Columbia specializing in Latin American affairs. He did graduate work at Yale and Michigan Universities specializing in Japanese language and history.

❖

Sonex, Inc., Philadelphia, Pa., announced the appointment of **John D. Clouse** (S'59) as Quality Assurance Manager. Formerly the Quality Control Head of the Teledatax Division of Sonex, Inc., Mr. Clouse will now head all quality assurance programs of the corporation. He joined the Sonex, Inc. organization in 1960 as a Quality Control Supervisor.

J. D. Clouse

For five years, prior to joining Sonex, Inc., Mr. Clouse was associated with the Tele-dynamics Division of American Bosch Arma Corp. A former U. S. Air Force Communications expert, Mr. Clouse majored in physics at LaSalle College, Philadelphia.

❖

Peter T. Millunzi (A'55–M'60) has been named Sales Manager for the Communications Accessories and Special Products divisions of Telex, Inc.

Mr. Millunzi, who has held supervisory sales and field engineering positions with several electronics and electrical equipment manufacturers, will be in charge of sales activities for a broad line of equipment including high-density pushbutton switches, headsets, microphones and other accessories for all types of communications installations.

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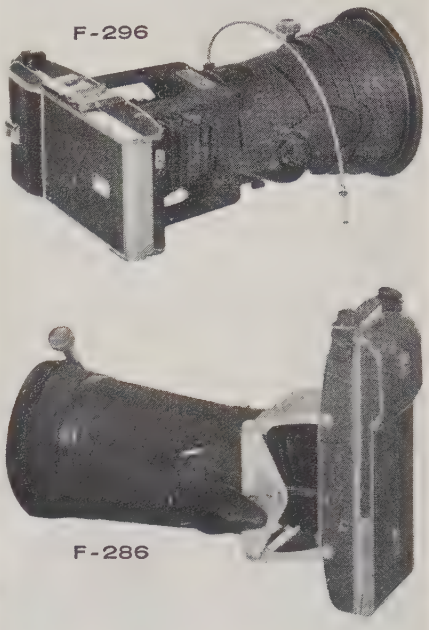

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For literature, prices and special bulletin on new High Speed films, write Dept. O, Fairchild Camera & Instrument Corp.

F-296 makes full size record of single transients or repetitive phenomena. F-286 records two half size images on each print. Both cameras have heavy duty Alphax #3 shutter. Speeds: 1 to 1/100 sec. "T" & "B". Fixed focus.

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INDUSTRIAL PRODUCTS DIVISION

Before joining Telex, Mr. Millunzi was General Sales Manager of American Monarch Corp. and prior to that headed all phases of development and market introduction of a micro-miniature relay at P. R. Mallory and Co., Inc.

He is an electrical engineering graduate of Marquette University.

❖

William J. Muller (M'59) has been named Product Manager for the Airtron plants, Linden, N. J., a division of Litton Industries.

W. J. Muller

In his new position, Mr. Muller is responsible for the design, development, and engineering of Airtron's flexible and rigid waveguide assemblies, foundry components and precision microwave accessories.

He previously spent six years as General Manager and Chief Engineer for Airtron-Canada, Ltd.

Mr. Muller began his work in electronics with Northern Electric Company and has also spent four years as special Products Manager and Chief Engineer with Renfrew Electric Company, Ltd.

He is a graduate of the University of Saskatchewan and a past member of the Society of Automotive Engineers.

❖

The appointment of **John E. Ebert** (J'41–A'43–SM'53) as Vice President in charge of Research, Development and Engineering for Weinschel Engineering Co., Inc., Kensington, Md., was recently announced.

J. E. Ebert

He comes to Weinschel with twenty years of experience in the microwave field. For the last nine years he was with FXR, Inc., Woodside, N. Y., where he was Vice President and Chief Microwave Engineer. While at FXR, Mr. Ebert was responsible for the design, development and other engineering aspects of FXR's proprietary line of microwave and electronic test equipment.

Mr. Ebert is a member of Sigma Xi, Tau Beta Pi and Eta Kappa Nu. He holds nine patents and is the author of a number of articles which have been published in professional journals.

❖

(Continued on page 86A)

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FILTERS/TUNERS
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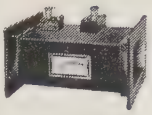
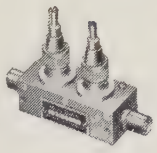


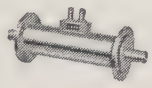
MicroGuide WAVEGUIDE DIRECTIONAL COUPLERS

Model No.	Frequency Range KMC	Coupling Attenuation db	Overall Length—Inches
WL30A	1.12 - 1.70	30	4¾
WS40A	2.60 - 3.95	40	3⅝
WC50A	3.95 - 5.85	50	3⅝
WX60A	8.20 - 12.40	60	1⅞



MicroMatch COAXIAL DIRECTIONAL COUPLERS DC OUTPUT

Model No.	Frequency Range Mcs.	Power Range Watts	RF Connectors
53663	2 - 30	0 - 1200	Type LC
576N	28 - 1000	0 - 400	Type N
402A8	28 - 1000	0 - 4000	1⅝" Flange
442A9	28 - 1000	0 - 12,000	3⅛" Flange



MicroMatch COAXIAL DIRECTIONAL COUPLERS RF OUTPUT

Model No.	Frequency Range Mcs.	Coupling Attenuation db	RF Connectors
308N2	500 - 1000	20	Type N
313N3	300 - 2000	30	Type N
362A7	30 - 1000	70	1⅝" Flange
382A6	120 - 1000	60	3⅛" Flange

COAXIAL FILTERS—LOW PASS

Model No.	Cutoff Freq. (Mcs.)	Power Rating (Watts)	RF Connectors
FLC41	700	1500	1⅝" Flange
FLC21	2200	100	N Type
FLC31	1200	200	⅞" Flange

COAXIAL LINE TUNERS

Model No.	Frequency Range Mcs.	Range of Correction	RF Connectors
151N	200 - 1000	Tunes residual mismatch to 1.000.	Type N
152N	500 - 4000		Type N

RF WATTMETERS Feedthru Type

Model No.	Frequency Range Mcs.	Power Range Watts	RF Connectors
711N	8 - 1000	0 - 30, 75, 300	Type N
712N	25 - 1000	0 - 2.5, 5, 10	Type N
706N	28 - 1000	0 - 400	Type N

RF WATTMETERS Absorption Type

Model No.	Frequency Range Mcs.	Power Range Watts	RF Connectors
621N	1 - 1000	0 - 120 mws	Type N
651N	25 - 1000	0 - 25, 100, 500	Type N
612A	44 - 1000	0 - 6000	3⅛" Flange

RF WATTMETERS Calorimetric Type

Model No.	Frequency Range Mcs.	Power Range (w)	RF Connectors
641N	0 - 3000	0 - 3, 10, 30, 100, 300	Type N

RF LOAD RESISTORS—50 AND 70 OHMS IMPEDANCE

Model No.	Frequency Range Mcs.	RF Power Dissipation (Watts)	RF Connectors
601N	0 - 3000	5	Type N
634N	0 - 3000	150	Type N
674N	0 - 3000	400	Type N, 70 Ohms
636N	0 - 3000	600	Type N
638A	0 - 2000	6000	3⅛" Flange

Equipment with type UHF, C, HN or other connectors can be supplied. Directional Couplers calibrated for 70 ohm use are also available.

MicroMatch® and MicroGuide® identify our coaxial and waveguide RF power and VSWR measuring instruments and associated microwave components designed to operate over 200 KC—12 KMC, at power levels from milliwatts to megawatts. ■ A patented* circuit in the directional couplers is designed to produce an output independent of frequency. ■ Although over 4500 different models have been produced, our "short order" departments add new models to meet requirements of industry and government. ■ Made in quantity to high Government standards, MicroMatch and MicroGuide combine high quality and low cost. ■ For more information, including a 68-page catalog, write M. C. Jones Electronics Co., Inc., Bristol, Connecticut.

*U.S. Letters Patent No. 2,588,390

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RCA now announces mass-production availability of the 2N2102, the "universal" triple-diffused planar silicon transistor designed for widest possible application in military and industrial equipment. It can replace up to 40% of all silicon transistors now on the market and will cover a vast majority of your Small-Signal and Medium-Power Applications.

The RCA 2N2102 features high switching speed, high pulsed beta (h_{FE}) at $I_C = 1$ amp, and controlled beta from $I_C = 10\mu a$ to 1 ampere. It has high breakdown-voltage ratings, high dissipation ratings, low saturation voltages and low output capacitances.

RCA's line of triple-diffused silicon planar transistors now includes the 2N699 and 2N1613.

Call your RCA Representative today or write RCA Semiconductor and Materials Division, Commercial Engineering, Section F-35-NN, Somerville, N.J.

RCA-2N2270, New Economy Version of RCA "Universal" Triple-Diffused Planar Silicon Transistor Now Available in Production Quantities.

Now you get many of the performance and versatility features of RCA's 2N2102 in a new economy version, the RCA 2N2270. The 2N2270 offers one of the greatest price/performance values in transistors today. The 2N2270 features operation at high junction temperatures—up to 200°C...very low output capacitance—15 pf max...high minimum gain bandwidth product—60 Mc...useful in applications from dc to 20 Mc...JEDEC TO-5 package.

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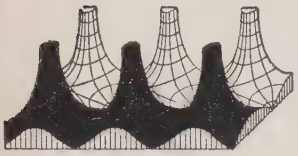
June, 1962 *Vol. 50* *No. 6*

Proceedings of the IRE

Poles and Zeros



One Hundred Kilomembers. With one milestone, IRE's fiftieth birthday, but thirteen days away, another historic milestone was reached. Total IRE membership on April 30: 100,075.

June. It's graduation time at engineering schools across the land. It is fitting to take a look at the yield of engineering degrees and at future prospects.

Table I shows that the output of electrical engineers at each degree level, B.S., M.S., and Ph.D., is 30 per cent of the total U. S. engineering output at the corresponding levels. These figures represent the strength, vigor, and present day attractiveness of careers in electrical engineering. But before we become too elated let us examine enrollment trends. Table I shows that engineering enrollment has been on the wane since 1958 and that B.S. output began to decline in 1960—just a normal time lag behind the enrollment drop because students are "in storage" in the colleges. Further decline is assured.

Engineering educators throughout the U. S. are concerned about decreasing engineering enrollments at a time when overall college enrollments are skyrocketing. Everyone has a theory, but no one seems to have defendable answers to the phenomenon, and no one has proven out an effective solution.

Some educators suggest that youth is caught up in the popular confusion between science and engineering as evidenced by a recent television broadcast in which the narrator said, "on this occasion it is fitting to honor the first great telephone scientist, Dr. Alexander Graham Bell, and the first telephone engineer, his assistant Mr. Watson"! Is the answer here to change departmental and degree designations in our colleges to "The Department of Electrical Science and Engineering"? The title is fitting. Approximate accreditation requirements of the Engineers' Council for Professional Development (ECPD—recall that IRE joined this organization in April, 1961) includes one year of engineering sciences in addition to one half year of basic sciences, one half year of mathematics, one half year of humanities, and the remainder of four years in other studies in engineering art, engineering design, and electives, etc.

Is it that our public schools are preparing qualified young men in insufficient numbers? Considerable progress has been made since Sputnik in bolstering high school offerings, but there is evidence that much remains to be done to increase the course-content capability of teachers. Summer institutes and summer schools are helping here but summer support for teachers who are continuing their studies is not provided by many high schools.

Or is it that "an engineering education" has become so over specified that the qualifications can be possessed only by an ever decreasing percentage of the population? Some schools are hopefully pursuing a plan of providing as many as "three tracks" to the B.S. degree: one curriculum is preparation for graduate study and the specific mission of research (about 30 per cent of engineering students might fit here); a second is for that large and effective group who specialize in development and design (about 50 per cent here); and a third is for engineers to be employed in sales, operations, and public relations (about 20 per cent of engineering students).

Essentially everyone in engineering education feels that our dwindling output of engineers is a serious problem and one which must be solved in the interest of the continuing development of our civilization.

Engineers and industrialists should join educators in concern about enrollment trends. Almost everyone agrees that the decrease is not "noise in the system" but is a serious, genuine trend.

Perhaps none of the preceding diagnoses or specifics are correct. What is the problem? What is a practical solution?

Table I—Data from 1962 ASEE Yearbook

	For All of Engineering							For EE
	1955	1956	1957	1958	1959	1960	1961	1961
Students	190,355	216,763	229,656	217,732	205,332	202,856	197,661	
B.S.	20,200	23,547	27,748	31,216	33,695	33,173	31,901	9,546
M.S.	4,444	4,678	5,203	5,751	6,725	7,128	8.084	2,327
Ph.D.	599	610	596	647	714	786	942	250

More on Cultures. Concerned IRE members rallied in grand style to the invitation in the February Poles and Zeros editorial, "The Two Cultures." Seven letters expressing views of the membership are included in the correspondence section (beginning page 1521). The views vary from wry humor (". . . in spite of the fact that the humanist is walking backwards into the future") to a most serious expression of forebodings ["can . . . (this body of engineers and scientists) . . . close the gaps of its own ignorance and face up to its own short comings in time to avert disaster, or . . . ."]

One of the letters ended with the postscript "I hope you enjoy reading this letter as much as I enjoyed writing it!" In turn, your editor hopes the reading membership gets pleasure, new insights, intellectual stimulation, and a feeling of gratitude to the writers for sharing their heart felt, but rarely expressed, views on this subject of such great importance to the worthwhileness and stability of the world we live in.

Required Reading. Still another reply to "The Two Cultures" expressed appreciation of the editorial and submitted a reprint of an essay which has appeared in several learned journals. This paper, "Modern Science and the Intellectual Tradition," which is reprinted on page 1452, gives an informative analysis of the cause and nature of the gap between the cultures, and ends by setting forth "the great challenge." Your editor urges you to read it.—T. F. J.

T. F. Jones, Jr.

Editor, 1962

Thomas F. Jones, Jr. (S'40–SM'48–F'62) is President-Elect of the University of South Carolina, Columbia, S. C. He will take office July 1, 1962. Since 1958 he has been Head of the School of Electrical Engineering at Purdue University, Lafayette, Ind., and is on the Board of Directors of General Electronic Laboratories, Cambridge, Mass., C-P Electronics, Columbus, Ind., and Hemothermatrol Corporation, Indianapolis, Ind.

He was born July 9, 1916, in Henderson, Tenn., and received his secondary education in the public schools of Wynne, Ark. In 1933 he was licensed by the FCC as Radiotelephone Operator First Class, and in 1935 was an operator of radio station KBTM in Jonesboro, Ark. He obtained his undergraduate engineering education at Mississippi State University, where he was awarded the B.S. degree in electrical engineering "With Highest Honors" in 1939. As a scholarship student he won the M.S. degree from the Massachusetts Institute of Technology in 1940. From 1941 to 1947 he was a physicist in the Underwater Sound Division at the Naval Research Laboratory in Washington, D. C., where he worked on electronic and acoustical problems related to submarine, antisubmarine, and mine warfare. In 1945 he was given the Meritorious Civilian Service Award by the United States Navy.

He returned to M.I.T. in 1947, where he earned the Sc.D. degree in 1952, and was involved in missile research, computing methods and equipment, and the development of electrical engineering curricula. He left M.I.T. in 1958 to join Purdue.

He has served for many years on the Education Committee of the IRE, on the Boards and Executive Committees of NEREM and NEC, and on the Executive Committee of the Boston Section and Region I. He has been on several *ad hoc* committees of the IRE and on the Editorial Board. He was active in the Professional Group on Education from its beginning, has held several offices, and is presently Vice Chairman.

Dr. Jones is a representative of the IRE on the Engineers Council for Professional Development.

Scanning the Issue

Modern Science and the Intellectual Tradition (Holton, p. 1452)—While it is not the custom of the PROCEEDINGS to deal with matters that are other than purely technical, on rare occasions an exception occurs. This article, reprinted from *Science*, is one such exception. Instead of the products of science, it discusses the images of science—as they appear to a world made up largely of nonscientists. Rather than demonstrating the continuities that exist within science, the article reveals the discontinuities that exist at its borders. In place of the hope for greater understanding, the author offers the warning that there will be less. It is unlikely that every reader will react to this article in the same way. Those engineers and scientists who wonder how society—and especially the intellectual forces within it which shape its attitudes—regards them as a group, may find some answers. Those who have the answers, may find some reasons. Those who wonder whether it matters in the first place, may find that it does. Whether the article alters one's opinions or re-enforces them, it is certain to sharpen one's view of our present culture.

Sophistication in Computers: A Disagreement (Kelly and Selfridge, p. 1459)—Last February the Professional Group on Information Theory published a special issue of TRANSACTIONS on Sensory Information Processing, containing over a dozen contributions from several disciplines bearing on human communication. As an appetizer to this sumptuous the fear that there will be less. It is unlikely that every fare there was offered an unusual joint examination of the subject of artificial intelligence and the value of the work that is being done on the theory of intelligent machines. The examination, which is reprinted here, is unusual not because it is joint but because the two authors are in disagreement. In order to pinpoint the area of disagreement, the authors first take up, and dispose of, some areas of agreement, such as: Can machines think? Do machines think? Will machines think? From there they move on to what they regard as a more significant question: Do sophisticated game-playing and problem-solving computer programs represent an advance toward the development of a genuine, generalized theory of intelligent machines? In answering, the authors disagree. In disagreeing, they have succeeded in bringing into sharp focus the basic ingredients of a growing topical controversy.

The TFT—A New Thin-Film Transistor (Weimer, p. 1462)—There is a great deal of interest today in thin-film circuits in which all the elements are deposited by evaporation upon an insulating substrate. It is confidently hoped that further advances in thin-film fabrication techniques will ultimately lead to truly integrated devices—devices of extreme complexity which can be made in one coherent piece. One of the main stumbling blocks to date has been the lack of a thin-film transistor which could be deposited by the same techniques as the rest of the circuit. This paper, because it provides a solution to this key problem, will be of great interest to the solid-state field and of major potential importance to future progress in microelectronics.

Packaged Electronically Tunable S-Band Traveling-Wave Maser System (Okwit and Smith, p. 1470)—The PROCEEDINGS has previously published a description of a packaged maser system of the cavity type. The present paper describes a packaged maser system of the traveling-wave type and presents some new performance data on it. This type is much superior to the cavity maser in several important performance attributes, including larger gain-bandwidth product, better stability, easier tuning and wider tuning range. As the first full description of the traveling-wave maser that has appeared in the PROCEEDINGS, this paper will interest many systems engineers in space communication, telemetry and radio astronomy, especially because the system has been designed for practical situations in the field.

Oscillators by Means of Magnetoresistance Effect (Sun, p. 1484)—Although the magnetoresistance effect is a fairly well-known phenomenon, relatively little has been done to put it to practical use. Magnetoresistive oscillators and amplifiers were investigated some time ago in Germany, but they suffered the disadvantage of being able to work only at liquid air and liquid hydrogen temperatures. The contribution of the present paper is the development of a practical oscillator which will operate at room temperature, a development made possible by the choice of indium antimonide as the active element. The result is a novel oscillator which is compact and shock-proof, requires no warm-up time, and can be started instantaneously. But more than that, this work calls attention to the fact that, in principle, any electronic device based upon the Hall effect can be replaced by a similar device based upon the magnetoresistance effect and as a result have a higher efficiency and sensitivity.

A Simplified Stability Criterion for Linear Discrete Systems (Jury, p. 1493)—A simplified method for testing the stability of linear systems has been developed which has significant computational advantages over commonly used methods. Because of these simplifications it is likely that users will be encouraged to apply stability tests to a substantially broader range of problems than heretofore. Nonspecialists will be happy to find that the paper has the added virtue of containing considerable tutorial material.

Linear Decision Functions, with Application to Pattern Recognition (Highleyman, p. 1501)—A pattern recognition system may be described in general as consisting of a receptor and a categorizer. It is the function of the receptor to provide the categorizer a set of quantities, or measurements, which characterize the physical sample to be recognized. It is then the task of the categorizer to decide, by applying some sort of decision criterion, to which of the allowable pattern classes, if any, the input pattern belongs. This paper is concerned with the design and properties of a categorizer. The author describes a particular class which does not require the designer to make questionable assumptions about the distribution and occurrence of the receptor measurements and also which is simple and inexpensive to implement—attributes which make this class of categorizer of practical as well as theoretical interest.

Gross Errors in Height Indication from Pulsed Radar Altimeters Operating over Thick Ice or Snow (Waite and Schmidt, p. 1515)—Ever since the Second Byrd Antarctic Expedition in 1933 there has been scattered evidence that ice and snow tend to be transparent to radio waves at certain frequencies. During the recent IGY activities in the Antarctic it was decided to make direct tests with 440 Mc pulsed-type radar altimeters over the thick landborne ice shelf. Results showed that, if a plane were to fly very low over the 500-foot-thick ice, its altimeter would read 900 feet instead of a few feet. This phenomenon has since been confirmed by further more exhaustive studies in both the Arctic and the Antarctic, the results of which are presented here. The fact that radar altimeters can be "snow-blind" (or ice-blind) at VHF and UHF is, of course, of vital importance to pilots who fly Arctic routes. Hence, the results reported here will be of substantial interest to those concerned with Arctic navigation.

Annual Indexes—The attention of readers is called to two important features of this issue: a consolidated index to all IRE TRANSACTIONS published during 1961, following page 1600, and a 1961 index to the Abstracts and References section of the PROCEEDINGS, in Part II of this issue.

Modern Science and the Intellectual Tradition*

GERALD HOLTON†

WHEN FUTURE GENERATIONS look back to our day, they will envy us for having lived at a time of brilliant achievement in many fields, and not least in science and technology. We are at the threshold of basic knowledge concerning the origins of life, the chemical elements, and the galaxies. We are near an understanding of the fundamental constitutents of matter, of the process by which the brain works, and of the factors governing behavior. We have launched the physical exploration of space and have begun to see how to conquer hunger and disease on a large scale. Scientific thought appears to be applicable to an ever wider range of studies. With current technical ingenuity one can at last hope to implement most of the utopian dreams of the past.

Hand in hand with the quality of excitement in scientific work today goes an astonishing quantity. The world-wide output is vast. There are now over 50,000 scientific and technical journals, publishing annually about 1,200,000 articles of significance for some branch of research and engineering in the physical and life sciences. Every year there are about 60,000 new science books and 100,000 research reports [1]. And the amount of scientific work being done is increasing at a rapid rate, doubling approximately every twenty years. Every phase of daily and national life is being penetrated by some aspect of this exponentially growing activity.

It is appropriate, therefore, that searching questions are now being asked about the function and place of this lusty giant. Just as a man's vigorously pink complexion may alert the trained eye to a grave disease of the circulatory system, so too may the spectacular success and growth of science and technology turn out, on more thorough study, to mask a deep affliction of our culture. And indeed, anyone committed to the view that science should be a basic part of our intellectual tradition will soon find grounds for concern.

Some of the major symptoms of the relatively narrow place science, as properly understood, really occupies in the total picture are quantitative. For example, while the total annual expenditure for scientific research and development in this country is now at the high level of over ten billion dollars, basic research—the main roots of the tree that furnishes scientific knowledge and the fruits of technology—has a share of about 7 per cent at best [2]. Correspondingly, a recent manpower study showed that of the 750,000 trained scientists and engineers, only 15,000 are responsible for the major part of the creative work being done in basic research [3]. Another nation-wide survey found that in 1958 nearly 40 per cent of the men and women who had attended college in the United States confessed that they had taken not a single course in the physical and biological sciences [4]. Similarly, in contrast to the overwhelming amount of, and concern with, science and technology today, the mass media pay only negligible attention to their substance; the newspapers have been found to give less than 5 per cent of their (nonadvertising) space to factual presentations of science, technology, and medicine, and television stations, only about 0.3 per cent of their time [4], [5]. In short, all our voracious consumption of technological devices, all our talk about the threats or beauties of science, and all our money spent on engineering development should not draw attention from the fact that the pursuit of scientific knowledge itself is not a strong component of the operative system of general values.

The Atomization of Loyalties

In the qualitative sense, and particularly among intellectuals, the symptoms are no better. One hears talk of the hope that the forces of science may be tamed and harnessed to the general advance of ideas, that the much deplored gap between scientists and humanists may be bridged. But the truth is that both the hopes and the bridges are illusory. The separation—which I shall examine further—between the work of the scientist on the one hand and that of the intellectual outside science on the other is steadily increasing, and the genuine acceptance of science as a valid part of culture is becoming less rather than more likely.

Moreover, there appears at present to be no force in our cultural dynamics strong enough to change this trend. This is due mainly to the atrophy of two mechanisms by which the schism was averted in the past. First, the common core of their early education and the wide range of their interests was apt to bring scholars and scientists together at some level where there could be mutual communication on the subjects of their individual competence; and second, the concepts and attitudes of contemporary science were made a part of the general humanistic concerns of the time. In this way a reasonable equilibrium of compatible interpretations was felt to exist, during the last century, between the concepts and problems of science on the one hand and of intelligent common sense on the other; this was

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also true with respect to the scientific and the nonscientific aspects of the training of intellectuals. Specialists, of course, have always complained of being inadequately appreciated; what is more, they are usually right. But although there were some large blind spots and some bitter quarrels, the two sides were not, as they are now in danger of coming to be, separated by a gulf of ignorance and indifference [6].

It is of course not my purpose here to urge better science education at the expense of humanistic and social studies. On the contrary; the latter do not fare much better than science does, and the shabby effort devoted to science is merely the symptom of a more extensive sickness of our educational systems. Nor do I want to place all blame on educators and publicists. Too many scientists have forgotten that especially at a time of rapid expansion of knowledge they have an extra obligation and opportunity with respect to the wider public, that some of the foremost research men, including Newton and Einstein, took great pains to write expositions of the essence of their discoveries in a form intended to be accessible to the nonscientist. And in the humanities, too many contributors and interpreters seem to scoff at Shelley's contention in his "Defense of Poetry" that one of the artist's tasks is to "absorb the new knowledge of the sciences and assimilate it to human needs, color it with human passions, transform it into the blood and bone of human nature."

It is through the accumulation of such neglects just as much as through deterioration in the quantity and quality of instruction given our future intellectual leaders that the acceptance of science as a meaningful component of our culture has come to be questioned. Again, this process is to a large extent merely one aspect of the increasing atomization of loyalties within the intelligentsia. The writer, the scholar, the scientist, the engineer, the teacher, the lawyer, the politician, the physician—each now regards himself first of all as a member of a separate, special group of fellow professionals to which he gives almost all his allegiance and energy; only very rarely does the professional feel a sense of responsibility toward, or of belonging to, a larger intellectual community. This loss of cohesion is perhaps the most relevant symptom of the disease of our culture, for it points directly to one of its specific causes. As in other cases of this sort, this is a failure of image.

Pure Thought and Practical Power

Each person's image of the role of science may differ in detail from that of the next, but all public images are in the main based on one or more of seven positions. The first of these goes back to Plato and portrays science as an activity with double benefits: Science as pure thought helps the mind find truth, and science as power provides tools for effective action. In Book Seven of the "Republic," Socrates tells Glaucon why the young rulers in the Ideal State should study mathematics: "This, then, is knowledge of the kind we are seeking, having a double use, military and philosophical; for the man of war must learn the art of number, or he will not know how to array his troops; and the philosopher also, because he has to rise out of the sea of change and lay hold of true being. . . . This will be the easiest way for the soul to pass from becoming to truth and being."

The main flaw in this image is that it omits a third vital aspect. Science has always had also a mythopoeic function—that is, it generates an important part of our symbolic vocabulary and provides some of the metaphysical bases and philosophical orientations of our ideology. As a consequence the methods of argument of science, its conceptions and its models, have permeated first the intellectual life of the time, then the tenets and usages of everyday life. All philosophies share with science the need to work with concepts such as space, time, quantity, matter, order, law, causality, verification, reality. Our language of ideas, for example, owes a great debt to statics, hydraulics, and the model of the solar system. These have furnished powerful analogies in many fields of study. Guiding ideas—such as conditions of equilibrium, centrifugal and centripetal forces, conservation laws, feedback, invariance, complementarity—enrich the general arsenal of imaginative tools of thought.

A sound image of science must embrace each of the three functions. However, usually only one of the three is recognized. For example, folklore often depicts the life of the scientist either as isolated from life and from beneficent action or, at the other extreme, as dedicated to technological improvements [7].

Iconoclasm

A second image of long standing is that of the scientist as iconoclast. Indeed, almost every major scientific advance has been interpreted—either triumphantly or with apprehension—as a blow against religion. To some extent science was pushed into this position by the ancient tendency to prove the existence of God by pointing to problems which science could not solve at the time. Newton thought that the regularities and stability of the solar system proved it "could only proceed from the counsel and dominion of an intelligent and powerful Being," and the same attitude governed thought concerning the earth's formation before the theory of geological evolution, concerning the descent of man before the theory of biological evolution, and concerning the origin of our galaxy before modern cosmology. The advance of knowledge therefore made inevitable an apparent conflict between science and religion. It is now clear how large a price had to be paid for a misunderstanding of both science and religion: to base religious beliefs on an estimate of what science cannot do is as foolhardy as it is blasphemous.

The iconoclastic image of science has, however, other components not ascribable to a misconception of its functions. For example, Arnold Toynbee charges science and technology with usurping the place of Christianity

as the main source of our new symbols. Neo-orthodox theologians call science the "self-estrangement" of man because it carries him with idolatrous zeal along a dimension where no ultimate—that is, religious—concerns prevail. It is evident that these views fail to recognize the multitude of divergent influences that shape a culture, or a person. And, on the other hand, there is, of course, a group of scientists, though not a large one, which really does regard science as largely an iconoclastic activity. Ideologically they are descendants of Lucretius, who wrote on the first pages of "De rerum natura," "The terror and darkness of mind must be dispelled not by the rays of the sun and glittering shafts of day, but by the aspect and the law of nature; whose first principle we shall begin by thus stating, nothing is ever gotten out of nothing by divine power." In our day this ancient trend has assumed political significance owing to the fact that in Soviet literature scientific teaching and atheistic propaganda are sometimes equated.

Ethical Perversion

The third image of science is that of a force which can invade, possess, pervert, and destroy man. The current stereotype of the soulless, evil scientist is the psychopathic investigator of science fiction or the nuclear destroyer—immoral if he develops the weapons he is asked to produce, traitorous if he refuses. According to this view, scientific morality is inherently negative. It causes the arts to languish, it blights culture, and when applied to human affairs, it leads to regimentation and to the impoverishment of life. Science is the serpent seducing us into eating the fruits of the tree of knowledge—thereby dooming us.

The fear behind this attitude is genuine but not confined to science: it is directed against all thinkers and innovators. Society has always found it hard to deal with creativity, innovation, and new knowledge. And since science assures a particularly rapid, and therefore particularly disturbing, turnover of ideas, it remains a prime target of suspicion.

Factors peculiar to our time intensify this suspicion. The discoveries of "pure" science often lend themselves readily to widespread exploitation through technology. The products of technology—whether they are better vaccines or better weapons—have the characteristics of frequently being very effective, easily made in large quantities, easily distributed, and very appealing. Thus we are in an inescapable dilemma—irresistibly tempted to reach for the fruits of science, yet, deep inside, aware that our metabolism may not be able to cope with this ever-increasing appetite.

Probably the dilemma can no longer be resolved, and this increases the anxiety and confusion concerning science. A current symptom is the popular identification of science with the technology of superweapons. The bomb is taking the place of the microscope, Wernher von Braun, the place of Einstein, as symbols for modern science and scientists. The efforts to convince people that science itself can give man only knowledge about himself and his environment, and occasionally a choice of action, have been largely unavailing. The scientist *as scientist* can take little credit or responsibility either for facts he discovers—for he did not create them—or for the uses others make of his discoveries, for he generally is neither permitted nor specially fitted to make these decisions. They are controlled by considerations of ethics, economics, or politics and therefore are shaped by the values and historical circumstances of the whole society [8].

There are other evidences of the widespread notion that science itself cannot contribute positively to culture. Toynbee, for example, gives a list of "creative individuals," from Xenophon to Hindenburg and from Dante to Lenin, but does not include a single scientist. I cannot forego the remark that there is a significant equivalent on the level of casual conversation. For when the man in the street—or many an intellectual—hears that you are a physicist or mathematician, he will usually remark with a frank smile, "Oh, I never could understand that subject"; while intending this as a curious compliment, he betrays his intellectual dissociation from scientific fields. It is not fashionable to confess to a lack of acquaintance with the latest ephemera in literature or the arts, but one may even exhibit a touch of pride in professing ignorance of the structure of the universe or one's own body, of the behavior of matter or one's own mind.

The Sorcerer's Apprentice

The last two views held that man is inherently good and science evil. The next image is based on the opposite assumption—that man cannot be trusted with scientific and technical knowledge. He has survived only because he lacked sufficiently destructive weapons; now he can immolate his world. Science, indirectly responsible for this new power, is here considered ethically neutral. But man, like the sorcerer's apprentice, can neither understand this tool nor control it. Unavoidably he will bring upon himself catastrophe, partly through his natural sinfulness, and partly through his lust for power, of which the pursuit of knowledge is a manifestation. It was in this mood that Pliny deplored the development of projectiles of iron for purposes of war: "This last I regard as the most criminal artifice that has been devised by the human mind; for, as if to bring death upon man with still greater rapidity, we have given wings to iron and taught it to fly. Let us, therefore, acquit Nature of a charge that belongs to man himself."

When science is viewed in this plane—as a temptation for the mischievous savage—it becomes easy to suggest a moratorium on science, a period of abstinence during which humanity somehow will develop adequate spiritual or social resources for coping with the possibilities of inhuman uses of modern technical results. Here I need point out only the two main misunderstand-

ings implied in this recurrent call for a moratorium.

First, science of course is not an occupation, such as working in a store or on an assembly line, that one may pursue or abandon at will. For a creative scientist, it is not a matter of free choice what he shall do. Indeed it is erroneous to think of him as advancing toward knowledge; it is, rather, knowledge which advances toward him, grasps him, and overwhelms him. Even the most superficial glance at the life and work of a Kepler, a Dalton, or a Pasteur would clarify this point. It would be well if in his education each person were shown by example that the driving power of creativity is as strong and as sacred for the scientist as for the artist.

The second point can be put equally briefly. In order to survive and to progress, mankind surely cannot ever know too much. Salvation can hardly be thought of as the reward for ignorance. Man has been given his mind in order that he may find out where he is, what he is, who he is, and how he may assume the responsibility for himself which is the only obligation incurred in gaining knowledge.

Indeed, it may well turn out that the technological advances in warfare have brought us to the point where society is at last compelled to curb the aggressions that in the past were condoned and even glorified. Organized warfare and genocide have been practiced throughout recorded history, but never until now have even the war lords openly expressed fear of war. In the search for the causes and prevention of aggression among nations, we shall, I am convinced, find scientific investigations to be a main source of understanding.

Ecological Disaster

A change in the average temperature of a pond or in the salinity of an ocean may shift the ecological balance and cause the death of a large number of plants and animals. The fifth prevalent image of science similarly holds that while neither science nor man may be inherently evil, the rise of science happened, as if by accident, to initiate an ecological change that now corrodes the only conceivable basis for a stable society. In the words of Jacques Maritain, the "deadly disease" science set off in society is "the denial of eternal truth and absolute values."

The main events leading to this state are usually presented as follows. The abandonment of geocentric astronomy implied the abandonment of the conception of the earth as the center of creation and of man as its ultimate purpose. Then purposive creation gave way to blind evolution. Space, time, and certainty, were shown to have no absolute meaning. All *a priori* axioms were discovered to be merely arbitrary conveniences. Modern psychology and anthropology led to cultural relativism. Truth itself has been dissolved into probabilistic and indeterministic statements. Drawing upon analogy with the sciences, liberal philosophers have become increasingly relativistic, denying either the necessity or the possibility of postulating immutable verities, and so have undermined the old foundations of moral and social authority on which a stable society must be built.

It should be noted in passing that many applications of recent scientific concepts outside science merely reveal ignorance about science. For example, relativism in nonscientific fields is generally based on farfetched analogies. Relativity theory, of course, does not find that truth depends on the point of view of the observer but, on the contrary, reformulates the laws of physics so that they hold good for every observer, no matter how he moves or where he stands. Its central meaning is that the most valid truths in science are wholly independent of the point of view. Ignorance of science is also the only excuse for adopting rapid changes within science as models for antitraditional attitudes outside science. In reality, no field of thought is more conservative than science. Each change necessarily encompasses previous knowledge. Science grows like a tree, ring by ring. Einstein did not prove the work of Newton wrong; he provided a larger setting within which some contradictions and asymmetries in the earlier physics disappeared.

But the image of science as an ecological disaster can be subjected to a more severe critique [9]. Regardless of science's part in the corrosion of absolute values, have those values really given us always a safe anchor? *A priori* absolutes abound all over the globe in completely contradictory varieties. Most of the horrors of history have been carried out under the banner of some absolutistic philosophy, from the Aztec mass sacrifices to the auto-da-fé of the Spanish Inquisition, from the massacre of the Huguenots to the Nazi gas chambers. It is far from clear that any society of the past did provide a meaningful and dignified life for more than a small fraction of its members. If, therefore, some of the new philosophies, inspired rightly or wrongly by science, point out that absolutes have a habit of changing in time and of contradicting one another, if they invite a re-examination of the bases of social authority and reject them when those bases prove false (as did the Colonists in this country), then one must not blame a relativistic philosophy for bringing out these faults. They were there all the time.

In the search for a new and sounder basis on which to build a stable world, science will be indispensable. We can hope to match the resources and structure of society to the needs and potentialities of people only if we know more about man. Already science has much to say that is valuable and important about human relationships and problems. From psychiatry to dietetics, from immunology to meteorology, from city planning to agricultural research, by far the largest part of our total scientific and technical effort today is concerned, indirectly or directly, with man—his needs, relationships, health, and comforts. Insofar as absolutes are to help guide mankind safely on the long and dangerous journey ahead, they surely should be at least strong

enough to stand scrutiny against the background of developing factual knowledge.

Scientism

While the last four images implied a revulsion from science, scientism may be described as an addiction to science. Among the signs of scientism are the habit of dividing all thought into two categories, up-to-date scientific knowledge and nonsense; the view that the mathematical sciences and the large nuclear laboratory offer the only permissible models for successfully employing the mind or organizing effort; and the identification of science with technology, to which reference was made above.

One main source for this attitude is evidently the persuasive success of recent technical work. Another resides in the fact that we are passing through a period of revolutionary change in the nature of scientific activity—a change triggered by the perfecting and disseminating of the methods of basic research by teams of specialists with widely different training and interests. Twenty years ago the typical scientist worked alone or with a few students and colleagues. Today he usually belongs to a sizable group working under a contract with a substantial annual budget. In the research institute of one university more than 1500 scientists and technicians are grouped around a set of multimillion-dollar machines; the funds come from government agencies whose ultimate aim is national defense.

Everywhere the overlapping interests of basic research, industry, and the military establishment have been merged in a way that satisfies all three. Science has thereby become a large-scale operation with a potential for immediate and world-wide effects. The results are a splendid increase in knowledge, and also side effects that are analogous to those of sudden and rapid urbanization—a strain on communication facilities, the rise of an administrative bureaucracy, the depersonalization of some human relationships.

To a large degree, all this is unavoidable. The new scientific revolution will justify itself by the flow of new knowledge and of material benefits that will no doubt follow. The danger—and this is the point where scientism enters—is that the fascination with the *mechanism* of this successful enterprise may change the scientist himself and society around him. For example, the unorthodox, often withdrawn individual, on whom most great scientific advances have depended in the past, does not fit well into the new system. And society will be increasingly faced with the seductive urging of scientism to adopt generally what is regarded—often erroneously—as the pattern of organization of the new science. The crash program, the breakthrough pursuit, the megaton effect are becoming ruling ideas in complex fields such as education, where they may not be applicable.

Magic

Few nonscientists would suspect a hoax if it were suddenly announced that a stable chemical element lighter than hydrogen had been synthesized, or that a manned observation platform had been established at the surface of the sun. To most people it appears that science knows no inherent limitations. Thus, the seventh image depicts science as magic, and the scientist as wizard, *deus ex machina*, or oracle. The attitude toward the scientist on this plane ranges from terror to sentimental subservience, depending on what motives one ascribes to him.

Impotence of the Modern Intellectual

The prevalence of these false images is a main source of the alienation between the scientific and nonscientific elements in our culture, and therefore the failure of image is important business for all of us. Now to pin much of the blame on the insufficient instruction in science which the general student receives at all levels is quite justifiable. I have implied the need, and most people nowadays seem to come to this conclusion anyway. But this is not enough. We must consider the full implications of the discovery that not only the man in the street but almost all of our intellectual leaders today know at most very little about science. And here we come to the central point underlying the analysis made above: the chilling realization that our intellectuals, for the first time in history, are losing their hold of understanding upon the world.

The wrong images would be impossible were they not anchored in two kinds of ignorance. One kind is ignorance on the basic level, that of *facts*—what biology says about life, what chemistry and physics say about matter, what astronomy says about the development and structure of our galaxy, and so forth. The nonscientist realizes that the old common-sense foundations of thought about the world of nature have become obsolete during the last two generations. The ground is trembling under his feet; the simple interpretations of solidity, permanence, and reality have been washed away, and he is plunged into the nightmarish ocean of four-dimensional continua, probability amplitudes, indeterminacies, and so forth. He knows only two things about the basic conceptions of modern science: that he does not understand them and that he is now so far separated from them that he will never find out what they mean.

On the second level of ignorance, the contemporary intellectual knows just as little of the way in which the main facts from the different sciences fit together in a picture of the world taken as a whole. He has had to leave behind him, one by one, those great syntheses which used to represent our intellectual and moral home—the world view of the book of *Genesis*, of Homer, of Dante, of Milton, of Goethe. In the mid-twentieth century he finds himself abandoned in a universe which is to him an unsolvable puzzle on either the factual or the philosophical level. Of all the bad effects of the separation of culture and scientific knowledge, this feeling of bewilderment and basic homelessness is the most terrifying. Here is the reason, it seems to me, for

the ineffectiveness and self-denigration of our contemporary intellectuals. Nor are the scientists themselves protected from this fate, for it has always been, and must always be, the job of the humanist to construct and disseminate the meaningful total picture of the world.

To illustrate this point we may examine a widely and properly respected work by a scholar who warmly understands both the science and the philosophy of the sixteenth and seventeenth centuries. The reader is carried along by his authority and enthusiasm. And then, suddenly one encounters a passage unlike any other in the book, an anguished cry from the heart:

> It was of the greatest consequence for succeeding thought that now the great Newton's authority was squarely behind that view of the cosmos which saw in man a puny, irrelevant spectator (so far as a being, wholly imprisoned in a dark room, can be called such) of the vast mathematical system whose regular motions according to mechanical principles constituted the world of nature. The gloriously romantic universe of Dante and Milton, that set no bounds to the imagination of man as it played over space and time, has now been swept away. Space was identified with the realm of geometry, time with the continuity of number. The world that people had thought themselves living in—a world rich with colour and sound, redolent with fragrance, filled with gladness, love and beauty, speaking everywhere of purposive harmony and creative ideals—was crowded now into minute corners in the brains of scattered organic beings. The really important world outside was a world hard, cold, colourless, silent, and dead; a world of quantity, a world of mathematically computable motions in mechanical regularity. The world of qualities as immediately perceived by man became just a curious and quite minor effect of that infinite machine beyond. In Newton, the Cartesian metaphysics, ambiguously interpreted and stripped of its distinctive claim for serious philosophical consideration, finally overthrew Aristotelianism and became the predominant world-view of modern times [10].

For once, the curtain usually covering the dark fears modern science engenders is pulled away. This view of modern man as a puny, irrelevant spectator lost in a vast mathematical system—how far it is from the exaltation of man that Kepler found through scientific discovery: "Now man will at last measure the power of his mind on a true scale, and will realize that God, who founded everything in the world on the norm of quantity, also has endowed man with a mind which can comprehend these norms!" Was not the universe of Dante and Milton so powerful and "gloriously romantic" precisely because it incorporated, and thereby rendered meaningful, the contemporary scientific cosmology alongside the current moral and aesthetic conceptions? Leaving aside the question of whether Dante's and Milton's contemporaries, by and large, were really living in a rich and fragrant world of gladness, love, and beauty, it is fair to speculate that if our new cosmos is felt to be cold, inglorious, and unromantic, it is not the new cosmology which is at fault, but the absence of new Dantes and Miltons.

And yet, Burtt correctly reflects the present dilemma. What his outburst tells us, in starkest and simplest form, is this: By having let the intellectual remain in terrified ignorance of modern science, we have forced him into a position of tragic impotence; he is blindfolded in a maze which he cannot traverse.

Once this is understood, the consequence also becomes plain. I find it remarkable that the intellectual today does not have even more distorted images and hostile responses with regard to science, that he has so far not turned much more fiercely against the source of apparent threats to his personal position and sanity—in short, that the dissociation has not resulted in an even more severe cultural psychosis [11].

But this, I am convinced, is likely to be the result, for there is at present no countercyclical mechanism at work. Some other emergencies of a similar or related nature have been recognized and are being dealt with: We need more good scientists, and they are now being produced in greater numbers; we need more support for studies in humanities and social science, and the base of support is growing gratifyingly. We sorely need to give our young scientists more broad humanistic studies —and if I have not dwelled on this it is because, in principle, this can be done with existing programs and facilities; for the existing tools of study in the humanities, unlike the tools in science, are still in touch with our ordinary sensibilities. But hardly anything being done or planned now is adequate to deal with the far more serious problem, the cultural psychosis engendered by the separation of science and culture.

One may of course speculate as to how one could make science again a part of every intelligent man's educational equipment—not because science is more important than other fields, but because it is an important part of the whole jigsaw puzzle of knowledge. A plausible program would include sound and thorough work at every level of education—imaginative new programs and curricula; strengthened standards of achievement; extension of college work in science to comprise perhaps one third of the total number of courses taken by the nonscience student, as used to be the rule in good colleges some fifty years ago; greater recognition of excellence; expansion of opportunity for adult education, including the presentation of factual and cultural aspects of science through the mass media. But while some efforts are being made here and there, few people have faced the real magnitude of the problem, in view of the large range and amount of scientific knowledge that is needed before one can "know science" in any sense at all. Moreover, while some time lag between new discoveries and their wider dissemination has always existed, the increase in degree of abstraction and in tempo of present-day science, coming precisely at a time of inadequate educational effort even by old standards, has begun to change the lag into a discontinuity.

This lapse, it must be repeated, is not the fault of the ordinary citizen; necessarily, he can only take his cue from the intellectuals, the scholars, writers, and teachers who deal professionally in ideas. It is among the latter that the crucial need lies. Every great age has been shaped by intellectuals of the stamp of Hobbes, Locke, Berkeley, Leibnitz, Voltaire, Montesquieu, Rousseau, Kant, Jefferson, and Franklin—all of whom would have

been horrified by the proposition that cultivated men and women could dispense with a good grasp of the scientific aspect of the contemporary world picture. This tradition is broken; very few intellectuals are now able to act as informed mediators. Meanwhile, as science moves every day faster and further from the bases of ordinary understanding, the gulf grows, and any remedial action becomes more difficult and more unlikely.

To restore science to reciprocal contact with the concerns of most men—to bring science into an orbit about us instead of letting it escape from our intellectual tradition—that is the great challenge that intellectuals face today.

References and Notes

[1] "Improving the Availability of Scientific and Technical Information in the United States," President's Science Advisory Committee Rept.; 1958.
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[3] "Naval Research Advisory Committee Report on Basic Research in the Navy," 1: 29, June 1, 1959; *Ibid.*, 2: 34.
[4] "The Public Impact of Science in the Mass Media," The University of Michigan, Ann Arbor; 1958.
[5] There is evidence that these figures have been increased by a factor of perhaps 1.5 since the survey was conducted. (See Hillier Krieghbaum, "Public Interest in Science News," *Science*, vol. 129, pp. 1092–1095; 1959.)
[6] Perhaps the most eloquent and influential voice among those who have recently addressed themselves to this problem is that of C. P. Snow in the Rede Lecture, "The Two Cultures and the Scientific Revolution. I recommend his book, although with certain reservations. See also Eric Ashby, "Technology and the Academics," Macmillan and Co., Ltd., London, Eng., 1958; and Frederick Burkhardt, "Science and the Humanities," Antioch Press, Yellow Springs, Ohio, 1959.
[7] See, for example, the disturbing findings of Margaret Mead and Rhoda Métraux, "Image of the Scientist among High-School Students," *Science*, vol. 126, p. 384; 1957.
[8] It is, however, also appropriate to say here that there has been only a moderate success in persuading the average scientist of the proposition that the privilege of freely pursuing a field of knowledge having large-scale secondary effects imposes on him, in his capacity as a citizen, a proportionately larger burden of civic responsibility.
[9] See, for example, Charles Frankel, "The Case for Modern Man," Beacon Press, Boston, Mass.; 1959.
[10] Edwin A. Burtt, "The Metaphysical Foundations of Modern Science," Doubleday and Co., Inc., New York, N. Y., 2nd ed., pp. 238–239; 1932.
[11] For a striking recent example see the virulent attack on modern science in the final chapter of Arthur Koestler's "The Sleepwalkers", The Macmillan Co., New York, N. Y.; 1959.

Sophistication in Computers: A Disagreement*

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Summary—**There is frequently more or less acrimonious discussion about artificial intelligence and intelligent machines and their place in science. Usually the discussion settles down to the reiteration of two points of view. This paper is concerned with the difference between them. Do they merely reflect two emotional or ethical biases, or is there an underlying technical judgment on which they disagree? The authors claim the latter and purport to show what that judgment is.**

INTRODUCTION

EVERYONE in the field of sophisticated computer programming recognizes that there are developing two antipodal schools of thought on the basic philosophy of *intelligent machines*. The exact nature of this disagreement is hard to specify, but most scientists and many laymen can be categorized as to *pro* or *con*. As we shall see later pro and con are not suitably descriptive words; nor are *optimistic* and *pessimistic*, nor *modern* and *old-fashioned*. But if the reader finds himself aware of the existence of these two groups, some such pair of words is needed to identify them. We shall use *left wing* and *right wing*, respectively, and temporarily leave their meaning as vague as the same words used in politics. Both sides are represented in the authors.

We wish to dismiss as rapidly as possible the crackpots on both sides. Moreover, some right wingers (and some left wingers, for that matter) base their opinions on deep and untestable religious grounds and prejudices. We, the authors, not being handicapped by the widespread biases and prejudices of everybody else, hope to explore the question and to show that underneath the dusty irrelevances and traditional pertinacities there really is a genuine scientific question on which scientists may properly differ. For example, the authors do. In this paper we try to uncover exactly what we differ on.

CAN MACHINES THINK?

One question about which thousands of words have been written (and more spoken) is "Can machines think?" While the responses (not necessarily *replies*) to this question are in fact highly symptomatic of left wingedness or right wingedness, the widespread disagreement about its meaning suggests that it does not fundamentally underlie the title dichotomy. However, we shall explore this straw man further.

First we hope to clear away some of the overlying hindrances. We shall not deal long with the suggestion that the thinking of man is inherently unduplicatable and unique as a matter of faith. First of all, such a suggestion is unprovable and not undeniable, and hence not very helpful or useful to scientists. (We remark that, even if it were unprovable and undeniable, that is, untestable, we should not therefore deem it *meaningless*, though some would.) Secondly, and more powerfully, people who maintain such a suggestion run a real risk of being demonstrated wrong. Thirdly, and most powerfully, statements which are merely assertions of faith are irrelevant to scientists doing their business of science.

Again, we do not concern ourselves with the argument that man is a machine because all his components follow well-known or less well-known physical laws. It is worth noticing that the direct evidence for this, especially in his brain, is skimpy, though we do not ourselves doubt it. The point is that it is irrelevant to whether we can simulate man with a probably much smaller and certainly very different machine.

Next we say that our differences are not merely semantic. Everybody seems to be aware that the meanings of words change. Even today, we can find a certain reluctance to call an activity *thinking* if it is evident that it can be done by machines. Furthermore, it is just not true that to be able to answer a question one must necessarily be able to define its terms either accurately or precisely. Any man who answered his wife's "Do you love me?" with "What do you mean by *love?*" would deserve what he got. Biologists are not greatly hampered by being unable to define, or even agree about, the meaning of *species* (or, for that matter, *life*). In fact, such disputes often turn out to be rather productive.

It is worth pointing out that in the question "Can machines think?" all three words are ambiguous enough to cause dissension. The word *can* itself, for example, demands clarification.

There are three degrees of possibility; a task is logically possible if it can be described free of contradiction; physically possible if it would not violate the accepted laws of physics; and practically possible at a particular time if it can actually be accomplished with current techniques and materials. These terms are all somewhat relative, but the last category is especially changeable. Examples:

It is impossible (logically) to find an integer between one and two.

It is impossible (physically) to build an antigravity space ship.

It is impossible (practically) to make good synthetic orange juice.

Now we believe that it is certainly logically and physically possible for a digital computer to do any sort

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of information processing[1] that a man can. This includes *thinking* or *invention* regardless of how broadly they are defined. As to what is practically possible, we will cover that in the following paragraphs.

We conclude therefore, that the question on which we differ is not "can machines think?"; that question we save for less sober and less meaningful occasions.

The Technological Time-Scale: The State of the Art

Even among those who hold that machines can think, in some sense, there are few, except for a rabid fringe on the left, who hold that they (machines) actually *are* thinking these days. What kind of prognosis can we make about artificial intelligence? In these primeval days, the evidence must be (and is) mostly in the form: there are many factors that comprise intelligence, and no one factor has been shown that machines are now incapable of. Creativity, ability to generalize, general language abilities, learning, have all been cited as abilities that are crucial. It is true that programs have been written and run that exhibit every one of them albeit in a limited domain and with special examples. How far can we extrapolate from those examples?

Thus, it is an important question whether those examples are so small as to be insignificant; but this question does not seem to be the functioning one for the disagreement. Nevertheless, we shall discuss its implications, because they seem to us significant to today's problems and are often misunderstood.

The first underlying implication is that the abilities we have been simulating have anything to do with the general question. While it might seem excruciatingly obvious that generalizing and learning have a great deal to do with powerful sophistication in computers, the fact remains that it is only a guess. It might turn out that the truly important abilities are ones we now discount or even some that we cannot describe and that the experiments the left wingers think to be so significant are indeed irrelevant.

A second underlying assumption is that the complexity of the intelligent computer program of the future is *not* of the essence. Most competent computer programs of today do not have a very complex structure, and most of us use Occam's razor whenever we can to simplify our tasks. We don't suggest here that this is wrong; but it might just be that extraordinary complexity of organization is the real source of the intelligence and flexibility that we want in the programs of the future.

There is a third much more disturbing assumption, disturbing to all of us for what it lightly suggests about the future of science. Supposing we have all the relevant factors well programmed; supposing we have a truly complex and adequate table of organization; supposing we have a stock of applicable history and experiences to feed our program. Why do we think that we can pull all these things together in a reasonable time and make it work? After all, most of our experience tells us that assembling a complex system and making it run are two very different matters generally separated by a long period of time. The kind of program envisioned for the future of computers is such a complex system by today's standards that we may well ask whether there is any point in bothering to assemble it at all.

We shall not attempt here to describe fully what we conceive to be the present state of the art and its manifold facets. We shall give one small example, which is historically interesting and goes back more than a hundred years. In the 16th Century, von Kempelen[2] claimed (fraudulently) to have constructed a chess-playing robot; the remarkable thing is that so many decent thinkers were taken in by a concealed dwarf.

Computing machines can play chess now, but not a respectable game. As a matter of fact, we are not even sure that there exists now a working chess-playing program of any sort.[3] There has been at least one, however.

The situation is different with checkers; Arthur Samuel from IBM has a program which plays well and can probably beat most readers. Some (for example, Allen Newell and Marvin Minsky) believe that the 7090, say, will be programmed to play master chess within a space of a few years. Others (for example, John Williams and George Miller) believe not.

It is an interesting and instructive example. There are many times in the course of a game where a player must have recourse to what are essentially routines very like those stored so well in a computer. For instance the classical ending of a king, bishop, and knight, against a solitary king can easily take more than the allowable fifty moves without practice. Many of the intricacies of the openings and their myriad variations are best memorized; that is not to say that a good working knowledge of the fundamental principles of the openings is not invaluable, because it obviously is—unfamiliar situations will often arise, especially with an opponent who may deliberately strive to produce them. But nearly all master players admit that they have effectively memorized a large number of openings.

Thus it seems likely that a successful (good, master, championship, or what have you) chess program will have several different modes of play. It will certainly need an effective evaluation function to handle totally unfamiliar positions, also an ability to handle trees of plausible moves, and so on. Given the almost negligible experience so far, what is the prognosis?

[1] By "information processing" we mean tasks whose performance can be measured by means of conventional I-O gear. We will not ask a computer to dig a ditch or eat a hamburger.

[2] H. W. Dudley and T. H. Tarnoczy, "The speaking machine of Wolfgang von Kempelen," *J. Acoust. Soc. Am.*, vol. 22, pp. 151–166; March, 1952.
R. Willis, "An Attempt to Analyze the Automatic Chess Player of M. De Kempelen with an Easy Method of Imitating the Movements of that Celebrated Figure," with 10 plates; 1821.

[3] It is a curious commentary that programs can be dismantled or lost. It has been said "In the computer art, one never has to program anything twice;" in practice, sad to say, programs *can* break down (from excessive correction, for instance) and *can* be dismantled or lost. We have never heard of a *program* wearing out, though cards and tapes do, of course.

Here is a curious thing: the dichotomy of left and right wing does not seem to match views of anticipated progress. As a matter of fact, the right-wing author thinks that application of techniques already tested can achieve a successful chess program; hence, it might take no longer than a year or so. The other author, a left winger, believes that we shall need some new techniques for success (namely, the ones he is strenuously advocating); and he believes that the minimum time is about three years.

Our position may then be compared with pioneers on the edge of a new continent. We have axes with which to cut down trees and build bridges. We have ladders to climb cliffs and boats to cross lakes. We have tested our axes on twigs, and made ladders and boats of paper. Shall we make the opposite shore? In principle we can cut down any tree, but obviously trees several miles in girth will take discouragingly long. We can span any river with bridges or boats in principle, but if the river is an Amazon with a thirty-knot current we may not be able to do it in fact. Then again, and here is a crucial point, the continent may be two light years across.

As pioneers, what we do *not* see is a river of molten lava, which would at one sight make us admit the inapplicability of our tools. Similarly, we do not see any clear-cut or easily statable need for new principles of science. If there is any difficulty of this kind it is more diffuse; we suggest that we need better ways of handling or discussing very complicated systems, for example. It will surely turn out that we discover many new principles; that is to be expected. It is not clear that any one of these new principles will in itself so violently reorganize our approaches that that part of thinking which was impossible before suddenly becomes possible afterwards. We guess, therefore, that it will be by small increments in understanding and abilities that we shall be able to reproduce thinking, and that the machines that do it will bear very little resemblance to the computing machines of today.

The Area of Disagreement

There is one remaining area in which to seek a definition of the relative position of the two schools of thought —the value to science and technology of the work that has been done on the theory of intelligent machines. Here we strike pay-dirt. The authors disagree with each other on every important phase of this question. One believes that a great amount of generality is possible in the approaches to pattern recognition and similar problems; the other insists that each problem must be attacked separately and that there is no stronger connection among them than the mere fact that the working of one problem serves as a not very profound practice for others. One author believes that although there are many useless papers published on intelligent machines ($\approx$90 per cent), there do exist some of value ($\approx$10 per cent); the other finds no paper on general theory helps in the solving of any particular problem, and in fact does not recognize anything worthy of being called a theory at all at present. One of us believes the concept of machine *learning* is extremely important; the other, that it is a completely valueless synonym for certain search and parameter adjustment techniques. One believes strongly in the possibility of a genuine scientific theory of intelligent machines and that present work at least scratches the surface; the other is still undecided on even the possibility, but is convinced that nothing of value has been described yet; that pseudo-theories based on "adaptive behavior," "advice-taking," "hill-climbing," and the like are too vague to serve as an actual recipe for writing intelligent programs and too naive to serve as useful heuristics for the programmer.

Man's ability to generalize has been the subject of wonder and speculation for ages. Leibnitz sought a "logic of invention" as distinct from classical deductive logic. Members of the left believe that with the aid of modern computers they have made progress, while their opponents think their efforts trivially transparent. Stated in its baldest form this problem of generalization is appalling to the mathematician. It is simply this: "Given a finite sequence of integers what is the next?" (We leave it to the reader to verify that any *learning* or *generalization* problem can be cast in this manner, although it need not be!) Consider a person playing this game exactly as stated, *i.e.*, a sequence of, let us say, fifteen integers is given him and he guesses the next one. Now we all know that for certain sequences the response will be consistent for nearly all subjects. Now suppose we tried to write a computer program to imitate the person. An extreme right winger would throw up his hands and declare we could never match human performance. A sensible right winger would use his intuition to think of easily programmed rules which would model the subject's behavior, but would not attach much general value to his efforts. A sensible left winger would attack the problem similarly but would claim his method had general value for other tasks. A member of the extreme left would not attack the problem directly. He would consider the input to be a long string of integers representing the subject's entire experience from birth (or perhaps from the beginning of life on earth) and try to duplicate the entire learning process.

We both realize that there is something inscrutable about man's ability to generalize. Members of the extreme right see no possibility of machines ever emulating this ability. Members of the extreme left think the problem is already solved! They are similar to the naive-realists or mechanists of the 18th century who thought that they did or were about to understand all of nature. More reasonable left wingers realize that complete understanding of any problem is illusory, but that we can reasonably expect present theoretical investigation to yield deeper insight into the problem of generalization. Reasonable right wingers on the other hand believe that the first step is yet to be taken toward a general theory and that efforts should be directed toward more specific tasks, and that until someone gets some good ideas he should refrain from cluttering the literature.

The TFT—A New Thin-Film Transistor*

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Summary—A thin-film transistor, TFT, fabricated by evaporation of all components on to an insulating substrate has been developed. Operation is based upon the control of injected majority carriers in a wide-band-gap semiconductor by means of an insulated control gate. Experimental units using microcrystalline layers of cadmium sulfide have yielded voltage amplification factors greater than 100, transconductances greater than 10,000 μmho, input impedances greater than 10^6 Ω shunted by 50 pf and gain-bandwidth products greater than 10 Mc. Switching speeds of less than 0.1 μsec have been observed.

Simple evaporated thin-film circuits incorporating the TFT have been built. Direct coupling between stages is permitted since the insulated gate electrode can be biased positively as well as negatively without drawing appreciable gate current. Modified forms of the TFT have been built for use as a flip-flop, an AND gate and a NOR gate in computer applications.

I. Introduction

THE POTENTIAL advantages of thin-film circuits have been largely unrealized to date because of the lack of a thin-film transistor which could be deposited by the same techniques upon an insulating substrate. The present paper will describe a new high-gain transistor[1] for which all components including the semiconductor and metal electrodes are deposited by evaporation upon a glass plate.

Owing to the extremely short lifetime of minority carriers in microcrystalline films it was assumed at the start of this development that a majority carrier type of thin-film triode had a greater probability of success than a bipolar type of transistor. Majority carrier transistors were proposed [1] as long ago as 1935 and have been investigated in various laboratories [2]–[4]. The best known of these is the Shockley unipolar [2] field-effect transistor based upon the pinch-off of a conduction channel by the expansion of the depletion layer in a back-biased p-n junction.

More recently, papers on a field-effect photo-transistor [5] and an analog transistor [6] using majority-carrier conduction in cadmium sulfide crystals have appeared. While the relatively low mobility of electrons in cadmium sulfide would not appear to recommend the material for a conventional transistor, cadmium sulfide offered some attractive features for exploratory studies of a thin-film triode. Single crystals of cadmium sulfide had been studied extensively [7], and considerable technological experience with thin films of cadmium sulfide had been acquired in the fabrication of photoconductive devices [8]. In addition, the wide-band-gap of cadmium sulfide made it well suited for the study of space-charge-limited currents in insulators [9], [10], a phenomenon which offered considerable potential for the development of new devices [6], [11]–[13].

The present investigation has yielded a new thin-film transistor [13] called the TFT whose performance utilizing microcrystalline layers of cadmium sulfide approaches that of commercial transistors made of single-crystal germanium or silicon. The surprisingly good performance of the TFT is due partly to the use of evaporation techniques which permit very small electrode spacings and gate widths. More important, however, has been the development of an insulating gate contact which permits operation in either the enrichment or depletion mode without drawing appreciable gate current. The enrichment mode is of particular interest from the standpoint of thin-film circuits since it permits direct coupling between stages. This mode of operation has not been used to date in commercially available transistors, although the effect was noted in some early experiments on "conductivity modulation" by Shockley and Pearson [14]. Recently, several single-crystal devices having an insulated control gate have been reported [15], [16]. The enrichment mode of operation has been discussed in connection with the "Electrolyte Field Effect" [17], "the Surface Field Effect Transistor" [15], the "Surface-Potential Controlled Transistor" [16], and the "Chargistor" [18].

The fabrication techniques employed in making the TFT are equally suitable for depositing interconnections and associated resistors, capacitors and diodes. Complete functional circuits containing many active and passive components can thus be fabricated in a single operation. As a simple illustration of the potential applications of the TFT a multistage thin-film amplifier was built. Other modifications of the TFT designed for particular circuit functions in computers will be described. These include an AND gate, a NOR gate and a simple flip-flop element.

II. Description of the Insulated-Gate TFT Structure

Fig. 1 illustrates one form of TFT which has yielded excellent results. The semiconductor film in most cases has been a microcrystalline layer of cadmium sulfide. The "source" and "drain" electrodes are ordinarily formed of metals which make a low resistance contact to the semiconductor. Evaporated gold is suitable for cadmium sulfide. The "gate" electrode may also be of gold but the contact must be formed in such a manner that a thin film of insulator is interposed between the metal electrode and the semiconductor. The thickness of the semiconductor is usually less than one micron and the source-drain spacing has been in the

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[1] The word transistor is used in its broadest sense here. The mode of operation of the device to be described is different from either the conventional unipolar or bipolar transistor.

range of 5 to 50 microns. The gate electrode is separated from the semiconductor by means of a thin evaporated layer of insulating material such as silicon monoxide. Fig. 2 shows a 1-in square glass plate (mounted on a lucite block) upon which three such transistors have been evaporated.

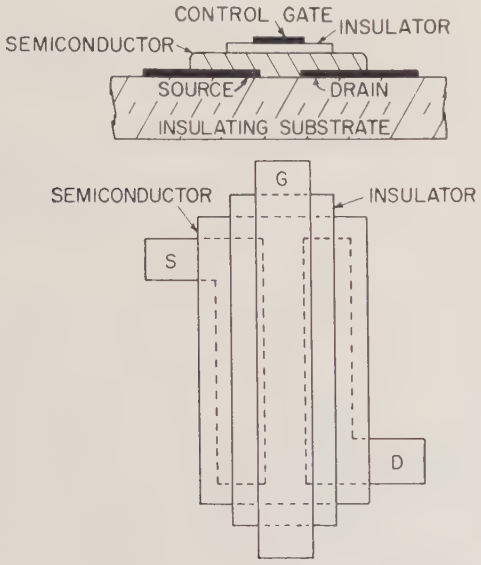

Fig. 1—Cross-sectional and plan view of an evaporated thin film transistor. The thickness of the evaporated layers is shown greatly exaggerated as compared to the lateral dimensions and to the thickness of the substrate.

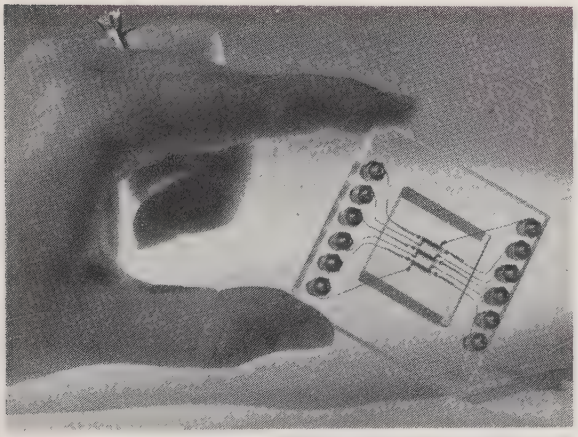

Fig. 2—A 1-in square glass plate (mounted on a lucite block) upon which 3 TFT's have been deposited.

A plot of drain current versus drain voltage for various values of positive gate bias is shown in Fig. 3 for one experimental unit. Since the drain current increases by a factor of 10 to 1000 as the gate bias is raised from zero to several volts positive, this type of operation is called the "enrichment" or "enhancement mode." This mode is to be contrasted with the "depletion mode" used in the conventional form of unipolar transistor having a *p-n* junction at the gate. In the depletion mode maximum useful drain current is obtained at zero gate bias while a negative gate bias "pinches off" the source-drain current by expanding the depletion layer. Although the TFT's can be designed for operation in either or both the enrichment and depletion mode, somewhat higher values of transconductance are usually obtained with the enrichment mode. The insulated gate permits operation in either mode without drawing appreciable gate current. Fig. 4 shows the characteristic curves of a TFT which operates with a gate bias near zero in either the enrichment or depletion mode.

The performance of the TFT can be predicted from the characteristic curves and a knowledge of the input capacitance. The unit shown in Fig. 3 has a transconductance of 5000 μa/v at a drain current of 6.5 ma and a gate bias approximately the same as the drain voltage. The voltage amplification factor derived from the curve is 50. The measured input capacitance of this unit was 300 pf, although this value was considerably larger than necessary. The gain-bandwidth product can be calculated from the approximate relation,

$$\text{G.B.} = \frac{g_m}{2\pi C_g} \tag{1}$$

where g_m and C_g are the transconductance and input capacitance, respectively. A value of 3 Mc was obtained, which is in good agreement with the measured frequency response curves on this unit.

More recently, TFT's similar to the above unit have been made with values of g_m as high as 25,000 μa/v for an input capacitance of less than 50 pf. Such units have yielded experimental gain-bandwidth products of about 12 Mc although the g_m/C ratio would indicate considerably higher capabilities. Oscillations have been obtained at frequencies up to 17 Mc, but no particular care has been taken to design the units for high frequency operation. All of the results quoted here were obtained with microcrystalline films of cadmium sulfide. There is excellent reason to believe that the performance can be extended considerably beyond the present values either by improved processing of the cadmium sulfide or by the use of a different semiconductor.

Although cadmium sulfide is an excellent photoconductor, no attempt was made in the above units to process the TFT's for maximum photosensitivity. The results quoted were obtained with the units in the dark. The effect of light, however, is to increase the transconductance for operation in either the enhancement or depletion mode. Fig. 5 shows characteristic curves for a unit operating in the enhancement mode in the dark and in the presence of light.

III. Physical Processes in the TFT

An approximate description of the operation of the insulated-gate TFT can be derived from consideration of a typical field-effect experiment [19], [20] such as used in the study of semiconductor surfaces. In this type of experiment a transverse field is applied to the surface of the semiconductor by means of a close-spaced metal plate. That part of the charge induced in the semiconductor surface which is not bound in surface states

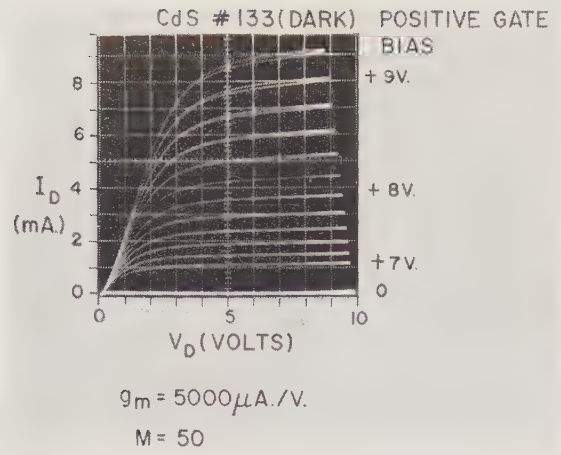

Fig. 3—Characteristic curves for an experimental cadmium sulfide TFT designed for operation in the "enrichment" mode. Drain current is plotted against drain voltage for different values of positive gate bias. (Source is grounded.) These curves were taken with the TFT in the dark.

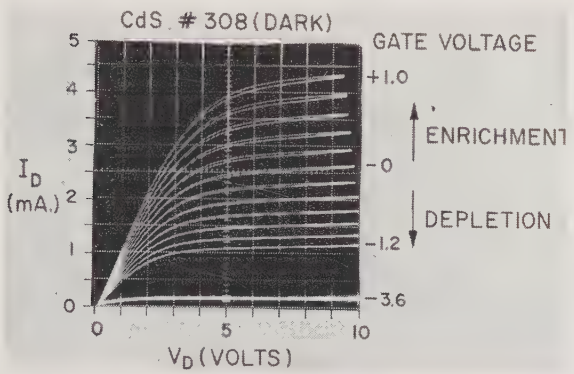

Fig. 4—Characteristic curves for an experimental TFT designed for operation in either the "enrichment" or the "depletion" mode. The hysteresis effect yielding the small loops noted in some units is now undergoing study.

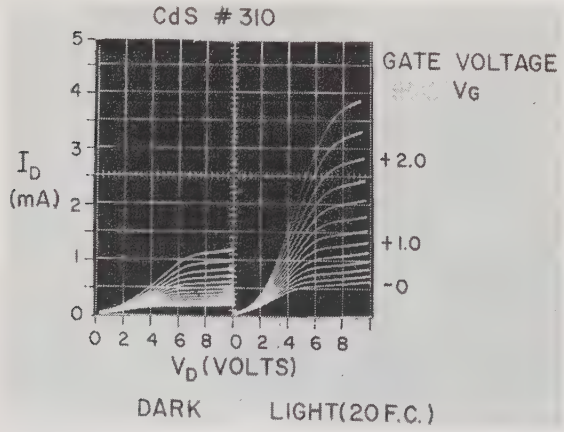

Fig. 5—Characteristic curves for an experimental TFT showing the effect of light. (Cadmium sulfide semiconductor.)

or other immobile sites will appear as a change in density of the mobile carriers. The surface conductivity can thus be either enhanced or diminished by the field plate by an amount depending upon the potential applied and the nature of semiconductor-insulator contact.

The TFT differs from most of the above field-effect experiments in the use of smaller dimensions and in the choice of a wide-band-gap semiconductor such as cadmium sulfide. In such a material the thermally-generated carrier density is small compared to the density of majority carriers which can be injected from the source electrode. With a suitable low resistance contact at the source, current densities of the order of hundreds or thousands of amperes per square centimeter can be drawn through the cadmium sulfide film in spite of its normally high resistance.

Fig. 6 shows an energy band picture of the contacts used at the source and gate electrodes in a TFT. At zero bias in a unit designed particularly for operation in the enhancement mode, the bands should bend up at the semiconductor-insulator interfaces as shown. When the gate is biased positively, electrons are drawn toward the interface, causing the bottom of the conduction band at the interface to be lowered relative to the Fermi level giving a highly conducting channel close to the insulator surface. (The small voltage drop in the semiconductor across the thickness of the layer is ignored in this drawing.) Conversely, a contact designed for the depletion mode of operation would aim to have a conducting surface channel present initially at zero gate bias which

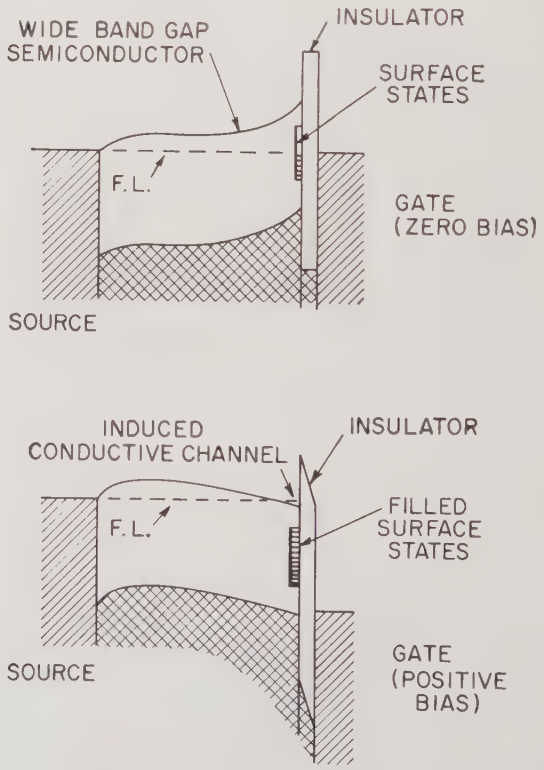

Fig. 6—An energy band picture of the "ohmic" source contact and the insulated-gate contact in a TFT designed for operation in the enrichment mode.

would then be depleted by operation with a negative gate bias.

An approximate expression for the transconductance of the TFT, based upon the above field-effect considerations, may be derived as follows: Consider a thin sheet of semiconductor of area $L \cdot W$ and a thickness h, separated from a close-spaced field plate by a thin dielectric spacer of thickness t. (See Fig. 7.) The dimensions L and W are assumed to be large compared to the film thicknesses, t and h. The positive potential V_g applied to the field plate (or gate) is assumed to be large compared to the potential difference between source and drain. A small increase in gate potential ΔV_g will draw Δn electrons/cm³ into the semiconductor given by

$$\Delta n = \frac{\text{total charge drawn in}}{e \cdot \text{total volume}} = \frac{C_g \cdot \Delta V_g}{e \cdot L \cdot W \cdot h} \cdot \qquad (2)$$

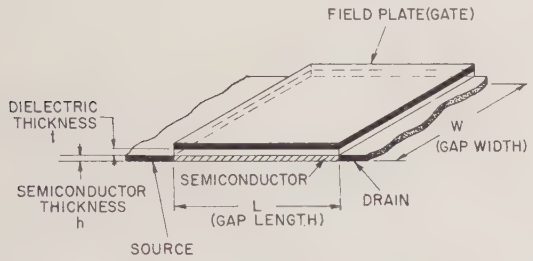

Fig. 7—Field-effect structure equivalent to the insulated-gate TFT.

The resulting increase in source-drain current is approximately

$$\Delta I_D = V_D \cdot \frac{Wh}{L} \Delta\sigma = V_D \cdot \frac{Wh}{L} \Delta n e \mu_d \qquad (3)$$

where

$\Delta\sigma$ = the change in conductivity of the semiconductor produced by the change in gate potential ΔV_g,
V_D = the source-drain potential difference and
μ_d = the effective drift mobility of the Δn electrons.

Combining (2) and (3) we obtain

$$\frac{\Delta I_D}{\Delta V_g} \cdot \frac{1}{C_g} = \frac{\mu_d V_D}{L^2} \quad \text{or} \quad \frac{g_m}{C_g} = \frac{\mu_d V_D}{L^2} \cdot \qquad (4)$$

The significance of small source-drain spacings is apparent since the gap length L is squared. The thickness of the dielectric spacer t and the width of the gate W appear implicitly in (4) in the gate capacitance. If we solved directly for g_m we would have

$$g_m = \frac{kW}{t} \frac{\mu_d V_D}{L} \qquad (5)$$

where k is the dielectric constant of the dielectric spacer. In general, (4) is more useful than (5) since g_m/C_g may be substituted in (1) to give the gain-bandwidth product of the device. It may be noted that the right-hand side of (4) is simply the inverse of the transit time of the electrons between the source and drain if the field were uniform.

In deriving (4) it was assumed that the drift mobility μ_d was a constant independent of variations in V_g. This is true in wide band-gap materials only under certain conditions. When the semiconductor contains many traps or surface states, the large fraction of trapped electrons may cause the effective drift mobility to be much smaller than the microscopic or Hall mobility by the factor θ:

$$\mu_d = \mu_D \cdot \theta = \mu_D \frac{n_F}{n_F + n_T} \qquad (6)$$

where

μ_d = effective drift mobility in the presence of traps,
μ_D = true drift mobility, which is assumed here to be equal to the Hall mobility,
n_F = is the free carrier density and
n_T = is the density of trapped carriers.

As the gate is made positive nearly all of the initial carriers drawn into the semiconductor may fall into the traps giving only a small increase in conductivity. For these electrons the effective drift mobility and the value of θ are very small. However, as the gate bias is further increased, most of the available traps should become filled (or otherwise inactivated) giving much larger increases in conductivity of the semiconductor. Under these conditions the drift mobility μ_d should approach a constant value equal to the Hall mobility ($\theta = 1$) and the g_m should become a constant independent of gate bias as predicted by (4).

The experimental results are in only partial agreement with the above analysis. The initial slow rise of drain current with gate voltage followed by a rapid rise at a large positive bias observed in Fig. 3 is consistent with the need for filling the surface states and traps to obtain adequate drift mobility. The surface state density for this unit calculated from the gate bias and gate capacitance is of the order of 10^{12} to 10^{13} per square centimeter, a not unreasonable value. However, as shown in Fig. 4, CdS units can be made which do not require a large positive gate bias for satisfactory operation. In such units the trapping state density is either much smaller or the traps have been filled by other processes.

The incorporation of shallow donors into the surface layer or the generation of free electrons by absorption of light represent two alternative ways of filling the traps.[2] Fig. 8 shows the variation in drain current with gate voltage for units having the two types of characteristics shown in Figs. 3 and 4.

[2] An entirely different process for neutralizing the effect of traps in the TFT is by emptying traps rather than by *filling* them. (See Bube [21].) Although sufficiently high fields may exist under some conditions in the gap region to empty shallow traps by impact ionization, it is not yet clear whether or not this process is a significant one in the TFT.

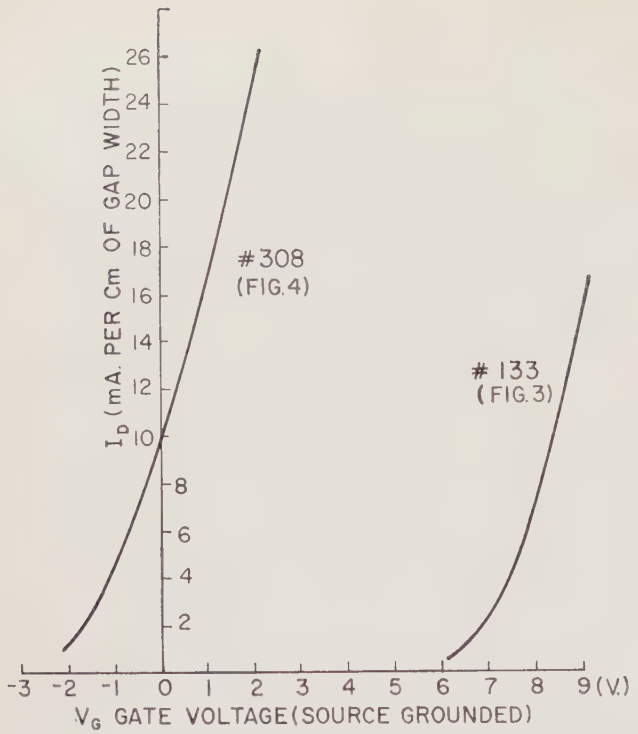

Fig. 8—Drain current versus gate voltage characteristics for TFT's of the types shown in Fig. 3 and 4.

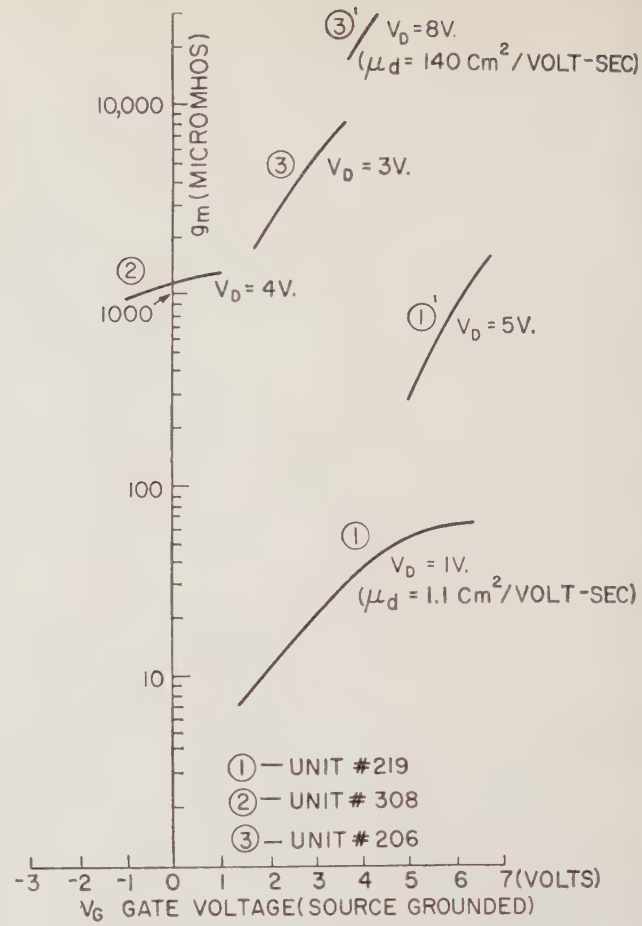

Fig. 9—Transconductance-versus-gate voltage for selected TFT's.

In Fig. 9 the experimental values of transconductance for widely differing units have been plotted as a function of gate bias. A log scale was chosen for g_m simply to accommodate the large range of data selected. From the above discussion one would expect g_m to reach a constant value at high positive gate biases as the effective drift mobility approaches the Hall mobility. Such a leveling off does indeed occur in curve 1 for drain voltage equal to 1 volt. The drift mobility could then be calculated from the g_m and the gate capacitance by the use of (4). For this calculation C_g was measured with an LC meter at a frequency of 150 kc and a normal positive gate bias. (The change in C_g with bias is usually less than 25 per cent.) The drift mobility computed in this manner was 1.1 cm²/v-sec, in fair agreement with independent measurements [11] of Hall mobility on polycrystalline cadmium sulfide layers. In curve 2 the g_m approaches a constant value of 1200 for $V_D = 4$ v, yielding a drift mobility of 6 cm²/v-sec. Curve 3 shows little tendency for g_m to reach a constant value even at low drain voltages.

It is clear that (4), which was derived assuming low drain voltages and a constant mobility, is inadequate for units operating with higher drain voltages as illustrated in curves 3 and 3′. Although the control mechanism in this case is probably more complex than can be explained solely by field effect considerations, it is interesting to use (4) as before to calculate the effective drift mobility. For curve 3′, μ_d was found to be 140 cm²/v-sec, a value considerably higher than would be expected from Hall mobility measurements on polycrystalline cadmium sulfide films. The reasons for this discrepancy are now being investigated. However, regardless of the explanation this result is exceedingly encouraging from the standpoint of device performance. Such performance makes a striking contrast with the early experiments on conductivity modulation [14] with evaporated germanium where the surface state density was so large as to severely limit the control action of the gate.

At drain voltages exceeding the gate bias the drain current in the usual TFT will saturate with drain voltage as shown in Fig. 3. This saturation effect is very important from the operational standpoint, since it is required for high voltage amplification factors. A rigorous analysis of the effect for the enrichment mode of operation is not presently available. From simple field-effect considerations, however, the saturation of drain current can be "explained" in terms of the following model: When the drain voltage becomes more positive than the gate, the induced channel adjacent to the insulator would be completely pinched off at the drain end were it not for the high field extending in from the drain. Owing to the thinness of the layers, however, the lateral component of the electrostatic field from the drain can penetrate only a short distance beneath the gate. The particular equipotential surface in the channel whose potential is equal to gate voltage thus remains relatively close to the drain electrode regardless of an increasing

drain voltage. The total current is limited by the electron flow *entering* this high field region, which, for drain voltages exceeding the gate voltage is consequently controlled by the gate voltage alone.[3] The failure of the drain current to completely saturate in practice would result from the gradual widening of the high field region due to incomplete shielding of the gate electrode. At much higher drain voltages (*e.g.*, 20 v in some cases) the drain current may again start rising rapidly with drain voltages. In terms of the above picture this effect could be caused by avalanche breakdown in the high field region near the drain, hole injection from the drain, or, in poor units, by leakage across the gate insulator.

The question of saturation of drain current in the TFT is considerably more complex than the preceding discussion would indicate. Experimental units have been made which gave large enhancement currents without saturation at drain voltages considerably exceeding gate voltage (see Fig. 10). Failure to saturate can arise from the existence of non-modulated current paths existing in series or in parallel with the conduction channel. Such characteristics would also be expected if the high resistivity region near the drain were prevented from forming. This might occur due to a premature setting in of any of the conditions enumerated above normally giving the second rise in current at high drain voltages.

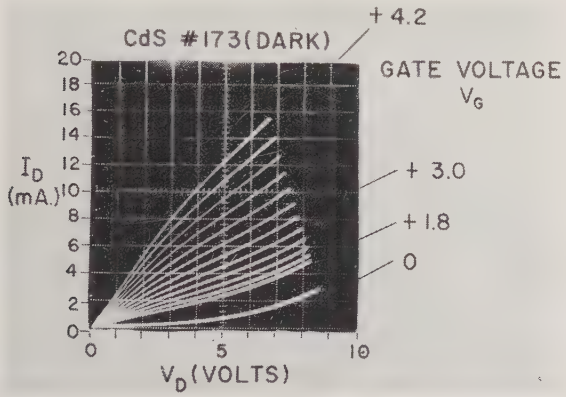

Fig. 10—Characteristic curves for a TFT showing failure of I_D to saturate.

It is not surprising that all aspects of the various TFT characteristics do not appear to be accounted for by field effect considerations. The spacings involved in the insulated-gate structure are finer and the stand-off insulator considerably thinner than normally found in field-effect experiments.[4] Although such dimensions permit the relatively high values of g_m and g_m/C which have been observed, close spacings may also introduce other phenomena, such as hot electron effects, diffusion of minority carriers and tunnelling phenomena. In spite of the added complexity introduced by such effects, they enhance the interest in the TFT from both the physics and the device application standpoint.

[3] In units which saturate at drain voltages less than gate voltage, the equipotential surface separating the low field region from the high field region will be correspondingly less than gate potential.

[4] DeWald in [17] achieved the equivalent of a very thin insulating spacer by the use of an electrolyte as a gate electrode.

IV. Alternate Forms of TFT's

Fig. 11 illustrates structural variations of the insulated-gate TFT which can be fabricated by the same evaporation techniques used for the standard structure of Fig. 1. Although experimental units have been made it is too early to attempt to evaluate their performance. The ability to fabricate the TFT in many different forms should be an advantage in designing TFT's for particular applications and in incorporating them into thin film circuits.

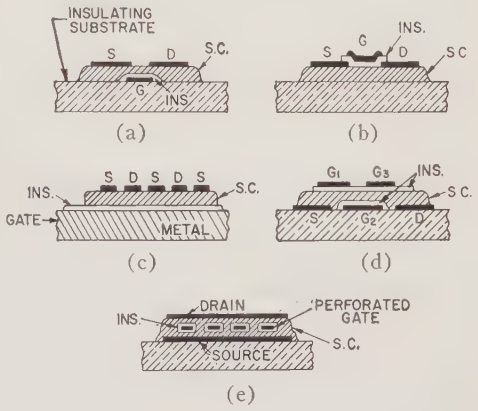

Fig. 11—Structural variations of the insulated-gate TFT.

The structure in Fig. 11(a) differs from the standard structure only in the sequence of evaporating the layers. In Fig. 11(b) all of the electrodes are applied on the same side of the semiconductor. Fig. 11(c) shows an interdigitated source and drain deposited upon an insulated metal gate for higher power output. Fig. 11(d) illustrates a pentode multiple gate structure designed to provide shielding between input and output.

Fig. 11(e) shows a layer-type TFT in which the control gate is a perforated metal film or an array of evaporated strips encased in insulator and embedded in the semiconductor. When biased positively or negatively with respect to the semiconductor the conductivity in the neighborhood of the apertures can be modulated, thus controlling the source-drain current. Although somewhat more lengthy to fabricate than the planar type TFT a possible advantage of the layer-type of unit may arise from a reduced source-drain transit time.

Many additional variations of the TFT will arise as the units are modified to serve particular functions in thin-film circuits. Several illustrations are given in Section VI.

V. Fabrication of the TFT

Although numerous thin-film techniques are available for fabricating the TFT, evaporation of all constit-

uents using movable masks for defining the electrode and semiconductor patterns has proved to be satisfactory for experimental purposes. A precision masking jig of a type originally developed for making a multiple electrode television camera tube target [22] provided a simple method of achieving very fine patterns, without requiring very fine masks. As indicated by (4), close spacing of the source and drain is desirable in the TFT in order to obtain the highest possible g_m and g_m/C ratios for a given semiconductor material. This type of jig is capable of reasonable accuracy with 5 micron spacings, and the technique can be extended to electrode dimensions of less than one micron.

Fig. 12 depicts the masking arrangement employed. A fine wire grill of variable wire spacing is mounted close to the glass substrate blank, whose lateral position relative to the wires can be adjusted from outside the vacuum enclosure. By moving the glass blank between successive evaporations gap spacings considerably smaller than the wire diameter can be deposited. An additional set of movable masks positioned between the wire grill and the evaporation source serves to define the length of the evaporated strips and provides lateral connections for evaporated circuits. This procedure avoids the problems associated with the use of extremely fine wires and greatly extends the versatility of a given set of masks.

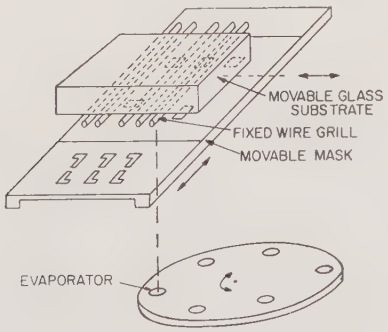

Fig. 12—Evaporation mask arrangement used in fabricating the TFT.

VI. Application of the TFT in Thin Film Circuits

The ability to fabricate circuits and components in the same operation points directly toward the "integrated circuit" concept [23] now being investigated in various forms in several laboratories. Although in an early stage of development, the TFT thin-film circuit is believed to offer some significant advantages when compared with existing techniques for forming transistors and circuits upon a single crystal block of silicon. An insulating substrate of nearly unlimited size permits a large array of circuits to be deposited on a single continuous support. In addition, the electrically inert base offers greater freedom in the design of the active elements and in the geometrical layout of intricate circuit patterns, since active and passive elements can be deposited in layers in any order. Both of these factors should lead not only to greater circuit density in complex devices but also to new applications where the available space for the electronics is at an absolute minimum. A TFT circuit could, in principle, be deposited upon any part of an existing device offering a few square millimeters of free surface. If the surface is a metal, a preliminary coating of insulator would be applied as substrate for the TFT.

The fabrication of thin film circuits incorporating transistors, resistors, capacitors and diodes can be carried out by the same evaporation techniques as described in the preceding section for the TFT. To illustrate the method a three-stage direct-coupled thin-film amplifier was built (see Fig. 13). Since many components are deposited simultaneously the number of operations required for a complete circuit increases very slowly or not at all with increasing complexity of the circuit. Complete circuits containing hundreds or thousands of active elements deposited in one evaporation sequence appear to be entirely feasible.

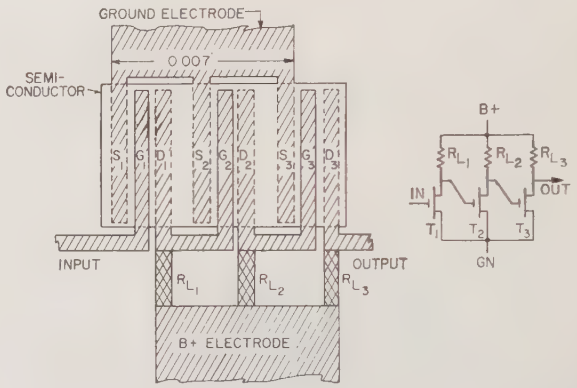

Fig. 13—A 3-stage direct-coupled thin film amplifier. Direct coupling is feasible because the insulated-gate TFT does not draw appreciable gate current.

Some preliminary consideration has been given to the application of the TFT in miniaturized computer circuits. Although the basic elements of a computer could be constructed using TFT triodes in combination with other thin-film components it may be advantageous to evaporate multi-electrode active elements designed particularly for the required function. Fig. 14 shows a direct-coupled flip-flop based upon the TFT. By inverting one of the triodes in the flip-flop the cross connections are simplified. Fig. 15 illustrates AND and NOR gates derived from the TFT. The semiconductor itself is used as the load resistor for the NOR gate.

The thin film circuits of Figs. 13–15 illustrate only crudely the potentialities of the TFT in integrated circuit design. It is apparent, however, that the distinction between components and circuits will become more and more diffuse when devices of extreme complexity can be fabricated in one coherent piece. To adequately design, build and use such integrated devices a new type of engineering skill will have to be developed.

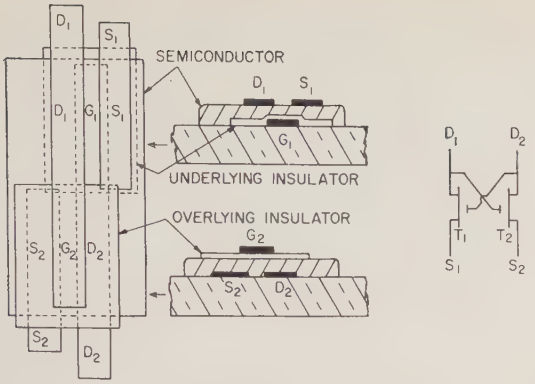

Fig. 14—A thin film flip-flop element equivalent to 2 TFT's with direct-coupled cross connections.

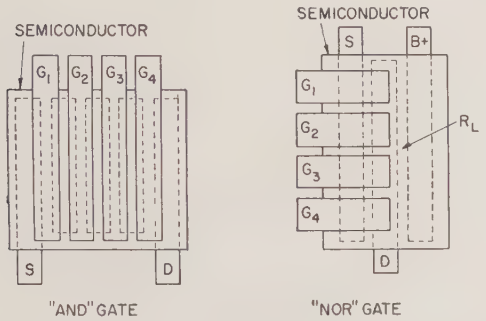

Fig. 15—Thin film AND and NOR gates derived from the TFT.

VII. Discussion and Conclusions

A striking aspect of the TFT development is the demonstration that a high-gain transistor can be built using a semiconductor as imperfect as a polycrystalline evaporated layer. Equally significant is that these transistors operate by the control of injected majority carriers with an insulated-gate structure. While the close spacing of electrodes has contributed to the surprisingly good performance the results are a convincing demonstration of the potentialities of devices utilizing injected majority carriers in wide-band-gap materials. Considering that TFT's have oscillated at frequencies up to 17 Mc using layers of the type yielding Hall mobilities of the order of 5 cm^2/v-sec, the prospect for improving the frequency response by one or two orders of magnitude appears good. This may require materials having higher mobility and structures with closer spacings.

On the basis of the results to date the TFT appears ready for evaluation in thin circuit applications. However, it is clear that much development work remains to be done. Questions such as stability, need for encapsulation, and ability to meet design tolerances, etc., have yet to be answered to fully assess the impact the TFT will have on circuit design. If these results are favorable (as preliminary tests appear to indicate) this impact could be very great indeed.

Acknowledgment

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Packaged Electronically Tunable *S*-Band Traveling-Wave Maser System*

S. OKWIT†, SENIOR MEMBER, IRE AND J. G. SMITH†

Summary—An *S*-band traveling-wave maser that operates over an 11 per cent tuning range is tuned by a single "frequency-calibrated" dial from 2120 to 2380 Mc. The maser has a relatively constant gain of 30 db and an instantaneous bandwidth of 22 Mc. It uses a comb-type slow-wave structure loaded on both sides with a $6\frac{1}{2}$ in length of 0.065 per cent chromium-doped ruby. Ferrimagnetic disks of yttrium iron garnet are periodically distributed in the slow-wave structure and provide sufficient reverse loss for short-circuit stability (100 db).

A relatively high gain per unit length of active ruby was realized because of: 1) optimization of the *C* axis orientation with respect to the dc and RF magnetic fields, 2) utilization of a four spin flip cross-relaxation process and 3) loading both sides of the comb structure with active ruby.

The traveling-wave maser and all the necessary auxiliary components have been packaged into an operational unit. The noise temperature of the system is about 10°K, and the short-term and long-term stabilities are ± 0.05 db and ± 0.1 db, respectively. A series of detailed measurements on the important electrical characteristics are described, and the performance data is presented. The system has been designed and successfully tested to meet military field environmental specifications.

I. Introduction

THE THREE-LEVEL solid-state maser proposed by Bloembergen [1] has stimulated wide interest in many fields where the ultimate in microwave receiver sensitivity is desired. Such masers have found applications in radio astronomy [2]–[6], satellite and intercontinental communications such as Project ECHO [7], and radar [8].

In the early development of practical maser amplifiers, the emphasis was placed on cavity masers. However, cavity masers have many undesirable characteristics such as small voltage gain-bandwidth products, relatively poor stability, difficult procedures required for tuning, etc. More recently emphasis has been placed on the use of distributed structures that have nonreciprocal gain [9]–[12]. This technique has eliminated or minimized all of the disadvantages of the cavity maser, and thus contributes a significant advance to the state of the art.

This paper describes the design considerations, operating characteristics and system performance of a traveling-wave maser operating in the 2120- to 2380-Mc telemetry band which is capable of military field applications.

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II. Design Considerations

A. Paramagnetic Crystal

Three-level solid-state masers have been operated using five paramagnetic crystals: gadoliniun ethyl sulfate [13], potassium chromi-cyanide [14], ruby [15], rutile [16] and emerald [17]. Of these five materials, ruby is the most desirable for operation in the microwave frequency range (below *K* band) because of its excellent electrical, physical and chemical characteristics. Consequently, ruby was chosen and used in all of the experiments discussed in this paper.

B. Gain and Bandwidth Characteristics

Amplification is obtained in a traveling-wave maser (TWM) by stimulating emission from an active material within a propagating structure. The electronic gain (in decibels) of a TWM is given by [9].

$$G_{\text{db}} = 27.3 \frac{SNF}{Q_m}. \tag{1}$$

where

S = Slowing factor = Velocity of light/group velocity,
N = Active length of TWM expressed in free-space wavelengths,
Q_m = Magnetic Q of the paramagnetic material,
F = Filling factor (a measure of the spatial interaction efficiency of the electro-magnetic wave and the paramagnetic spin system).

The 3-db bandwidth that results from operating the TWM at a given gain is [9]

$$B = B_m \left(\frac{3}{G_{\text{db}} - 3} \right)^{1/2}, \tag{2}$$

where B_m is the line width of the paramagnetic crystal (about 60 Mc for ruby). Eq. (2) shows that, for a gain of 30 db, the maser 3-db bandwidth would be about 20 Mc.

C. Slow-Wave Structure

To obtain appreciable gain in a TWM, it is necessary to strongly couple the microwave RF signal to the crystal. There are several techniques for doing this [18]; however, the most desirable technique is to use a resonant slow-wave circuit as the propagating structure. Several different types of resonant slow-wave structures were investigated and evaluated. The comb structure,

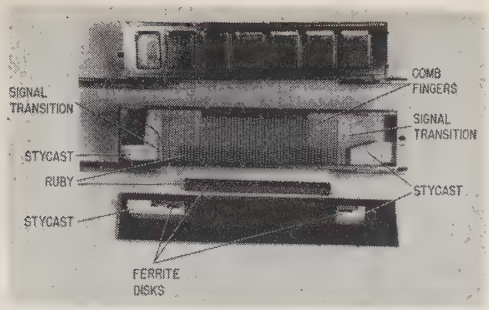


Fig. 1—Comb-type slow-wave structure.

which was first used in a TWM by DeGrasse, *et al.* [9], was determined to be the most suitable for our application.

A photograph of the structure that was evolved is shown in Fig. 1. Both sides of the comb structure were loaded with rectangular ruby slabs to increase the filling factor. (This is discussed further in Section IIIB.) Figs. 2 and 3 show the measured ω-β characteristics of the structure (measured at liquid-helium temperatures) and the slowing factors calculated from these characteristics. The slowing over the 2120- to 2380-Mc tuning range is relatively constant—that is, 72 at band center and increasing to about 83 at the band edges. The lower and upper cutoff frequencies are 2080 and 2480 Mc, respectively, which yield an overall bandwidth of 400 Mc. Only about 65 per cent of this over-all bandwidth was found to be useable because of matching considerations. The SWR over this 65 per cent band was measured to be less than 1.5 with an average insertion loss of about 4 db (see Fig. 4).

D. Isolator Methods

To achieve gain stability in the presence of generator and load variations, the maser must have unilateral forward gain and reverse loss. There are two practical solutions to this problem [18].

1) An inactive ruby crystal (heavily doped to prevent inversion of the signal transition) used as an isolator.
2) A ferrimagnetic material (such as polycrystalline YIG) used as an isolator.

Each of these solutions requires the use of a microwave structure with well-defined regions of circular or elliptical polarization.

In addition, the method of obtaining isolation should have the same static magnetic field requirements for isolator resonance as it does for maser action.

1) Inactive Ruby Crystal

The inactive ruby crystal method is ideal insofar as the coincident field requirement is concerned. However, for the frequencies of interest the amount of isolation that can be obtained for a circularly polarized field is

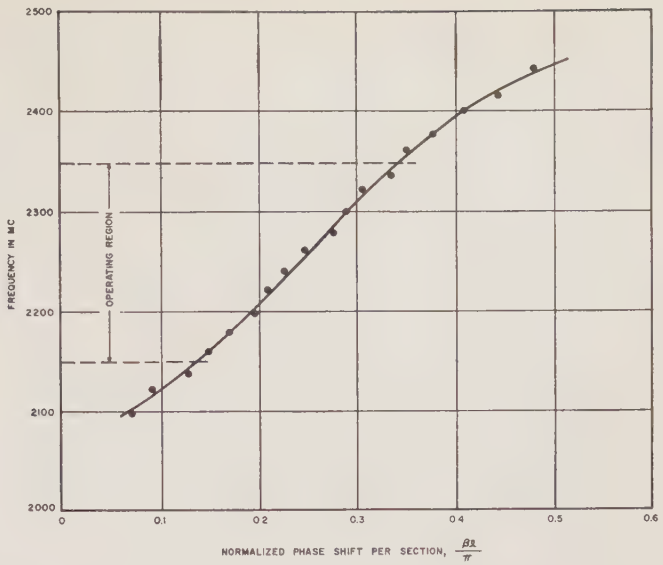


Fig. 2—ω-β characteristic of final comb structure.

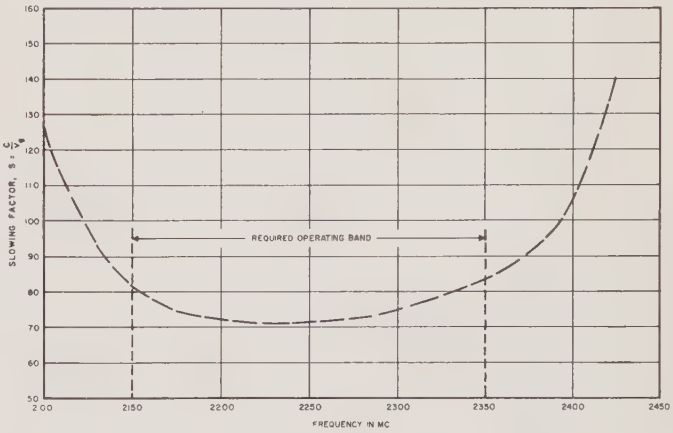


Fig. 3—Slowing factor of final comb structure.

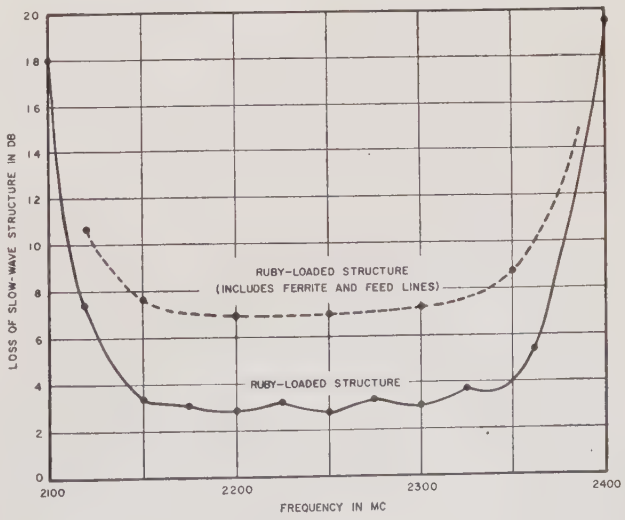

LOSS OF SLOW-WAVE STRUCTURE IN DB
RUBY-LOADED STRUCTURE (INCLUDES FERRITE AND FEED LINES)
RUBY-LOADED STRUCTURE
FREQUENCY IN MC

Fig. 4—Dissipative losses of TWM structure.

insufficient for the degree of stability desired. This can be seen from the following:

The loss of the inactive material in the forward direction can be expressed as

$$L_{\mathrm{db}}{}^{+} = 27.3\,\frac{SN}{Q_m{}^{+}} \tag{3}$$

and the loss in the reverse direction as

$$L_{\mathrm{db}}{}^{-} = 27.3\,\frac{SN}{Q_m{}^{-}} \tag{4}$$

where the entire ruby is assumed to be contained in the plane of circular polarization, and where $Q_m{}^{+}$ and $Q_m{}^{-}$ are the ruby magnetic Q's associated with the forward and reverse directions, respectively. The figure of merit of the ruby isolator is thus

$$F = \frac{L_{\mathrm{db}}{}^{-}}{L_{\mathrm{db}}{}^{+}} = \frac{Q_m{}^{+}}{Q_m{}^{-}}\,. \tag{5}$$

The Q_m is inversely proportional to the square of the signal transition matrix elements of the perturbation Hamiltonian. Hence, using the notations of [19] and [20] (corrected for negative D values), we obtain

$$F = \left[\frac{\langle E_1 |\ 2\beta H_{\mathrm{rf}}{}^{+}\cdot S\ |\ E_2\rangle}{\langle E_1 |\ 2\beta H_{\mathrm{rf}}{}^{-}\cdot S\ |\ E_2\rangle}\right]^2, \tag{6}$$

where $H_{\mathrm{rf}}{}^{+}$ and $H_{\mathrm{rf}}{}^{-}$ are the right and left circularly polarized RF magnetic fields for the forward and reverse directions of propagation.

The circular polarization for the orientation used is defined in the Y-Z plane, where the X direction is parallel with the dc magnetic field (see the coordinate system of Fig. 5).

$$H_{\mathrm{rf}}{}^{+} = iHy\cos\omega_s t - H_z \sin\omega_s t. \tag{7}$$

$$H_{\mathrm{rf}}{}^{-} = iHy\cos\omega_s t + H_z \sin\omega_s t. \tag{8}$$

The perturbation Hamiltonian $(2\beta H_{\mathrm{rf}}\cdot S)$ then becomes

$$2\beta(iH_y S_y - H_z S_z) \qquad \text{for } H_{\mathrm{rf}}{}^{+}. \tag{9}$$

$$2\beta(iH_y S_y + H_z S_z) \qquad \text{for } H_{\mathrm{rf}}{}^{-}. \tag{10}$$

Substituting into (6) yields

$$\left[\frac{(\beta_i + \gamma_r)}{(\beta_i - \gamma_r)}\right]^2, \tag{11}$$

where β_i and γ_r are coefficients of the direction cosines of the y and z components of the magnetic moment. These coefficients have been tabulated and plotted as a function of magnitude and angular orientation of the dc magnetic field [19]. Using the tables in [19], (11) has been evaluated as a function of frequency for an H_{dc} angular orientation of 90° with respect to the C axis. Fig. 6 is a plot of the results obtained. The maximum figure of merit that can be obtained for a circularly

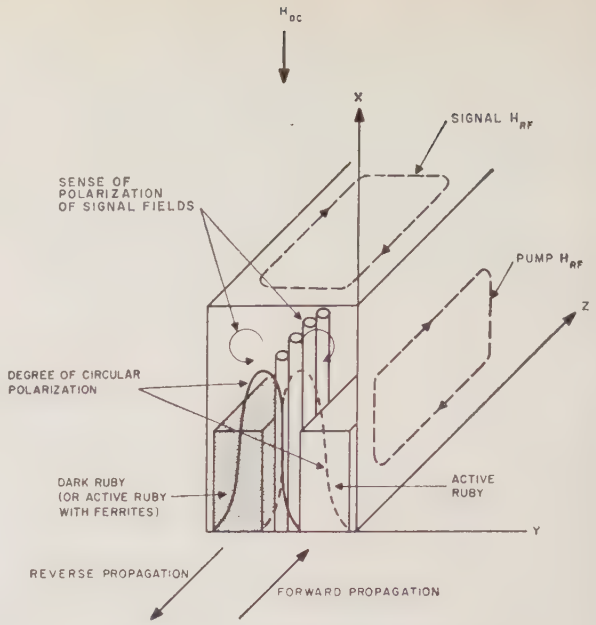


Fig. 5—Circular polarization in comb structure.

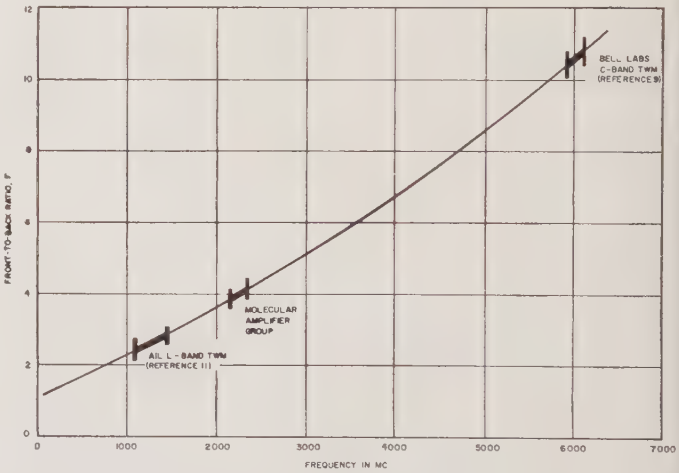

FRONT-TO-BACK RATIO, F
FREQUENCY IN MC
BELL LABS C-BAND TWM (REFERENCE 9)
MOLECULAR AMPLIFIER GROUP
ALL L-BAND TWM (REFERENCE 11)

Fig. 6—Theoretical front-to-back ratio of signal transition (1-2) of ruby crystal for circular polarization.

polarized field in the 2120- to 2380-Mc range is about 4.[1] which is not efficient enough to obtain high reverse loss and good stability without seriously degrading the forward gain. In addition, this method has the disadvantage of absorbing pump power.

2) Ferrimagnetic Material

The ferrite-isolator method eliminates the disadvan-

[1] It is possible to obtain infinite figures of merit for specific combinations of 1) C axis orientation with respect to the RF magnetic fields, and 2) field ellipticity in the ruby crystal. However, even though the figure of merit can be infinite, the resulting matrix elements become small and this causes a decrease in field interaction and a subsequent low reverse loss-per-unit-length. This is discussed in more detail in Section IIIB.

It is more practical in this discussion to use circular polarization since we will also be dealing with ferrimagnetic resonance.

tages that occur in the inactive ruby crystal—that is, poor figure of merit, and pump power absorption. However, the problem of obtaining coincident dc magnetic fields for isolator resonance and TWM amplification must be solved.

Since the TWM operates at liquid-helium temperatures, a ferrite whose resonance line width does not broaden excessively at low temperatures must be used. A broadening in line width causes degradation in the figure of merit. The best ferrite now available for use at low temperatures (in the 2120- to 2380-Mc region) is polycrystalline YIG. This material has little line broadening when cooled to liquid-helium temperatures [21] and has a saturation magnetization of 1750 gauss at room temperature (changing to about 2480 gauss at 4.2°K).

The problem of coincident magnetic fields can be solved by choosing a ferrite geometry whose demagnetizing fields [22] cause coincidence. The ferrite resonance condition is given by the general Kittel equation [23]

$$\frac{f_r}{\gamma} = \left\{(H_z-(N_z-N_x)4\pi M_s][H_z-(N_z-N_y)4\pi M_s]\right\}^{1/2} \quad (12)$$

where

f_r = Frequency of ferrimagnetic resonance, in Mc.
γ = Gyromagnetic ratio = 2.8 Mc/oersted (this definition differs by 2π from that in most references, where it is defined in terms of angular frequency).
H_z = Applied magnetic field in oersteds.
N = Demagnetizing factors in the direction of the three Cartesian coordinates.
$4\pi M_s$ = Saturation magnetization of the ferrite in gauss.

For a ferrite disk, (12) reduces to

$$\frac{f_r}{\gamma} = H_z - (N_z - N_t)4\pi M_s, \quad (13)$$

where $N_x = N_y = N_t$.

Furthermore, for a ferrite sphere,

$$\frac{f_r}{\gamma} = H_z \quad (14)$$

since N_x and $N_y = N_z$.

Fig. 7 is a plot of resonant frequency vs applied magnetic field H_z for the following:

1) Ruby crystal with C axis at 90° with respect to H_z.
2) Ferrite sphere.
3) Computed values for YIG disks with various t/d ratios at room temperature ($4\pi M_s = 1750$ gauss).

Superimposed on Fig. 7 are measured values taken at room temperature of YIG disks with several t/d ratios. The measured magnetic field required for resonance is lower than that predicted theoretically. It was also observed that at low fields the slope of the measured data deviates considerably from the 2.8 Mc/oersted straight-line relationship. We believe this is due to the fact that the ferrite is not completely saturated.

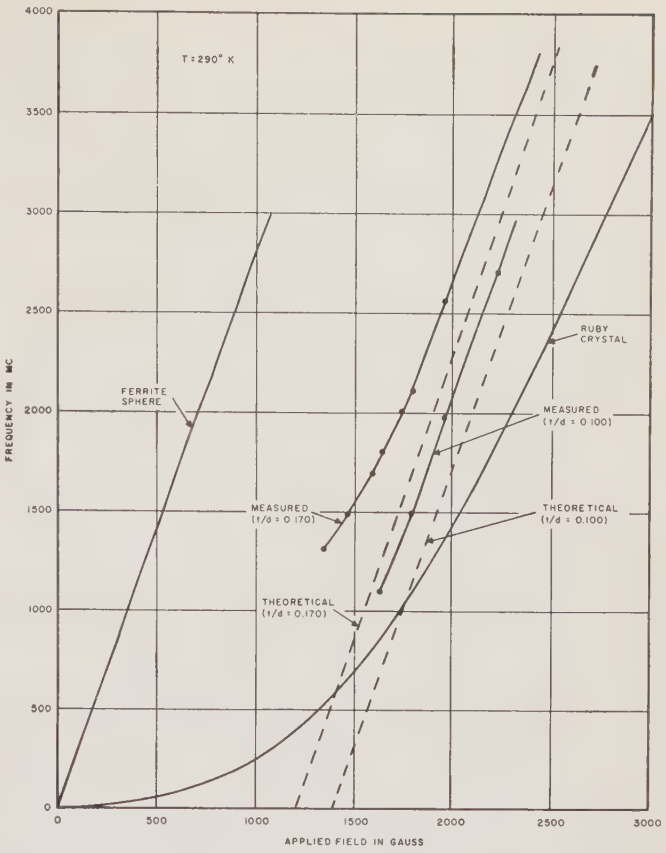


Fig. 7—Resonant frequency vs applied magnetic field for ruby crystal and YIG ferrite disks.

Measurements of the polycrystalline YIG disks were made at 4.2°K and 77°K (Fig. 8). This figure shows that 1) the field requirements at 4.2°K and 77°K are almost identical (implying that the saturation magnetization does not change greatly from 77°K to 4.2°K), 2) the optimum t/d ratio for coincidence is about 0.105 and 3) the slope of the measured values deviates from the 2.8-Mc/oersted straight-line relationship by more than the room-temperature measurements (Fig. 7). This deviation is to be expected since the saturation magnetization has increased from 1750 gauss at room temperature to about 2480 gauss at low temperatures. Thus, the ferrite is further away from saturation at 4.2°K. Furthermore, the 1-db bandwidth of the ferrite resonance is about 150 gauss, which is caused in part by low-temperature broadening as well as by the slight differences in the effective t/d ratios of the disks that result from 1) the dimensional tolerances, and 2) the tilting caused by mounting variations. (A slight amount of broadening is a desirable effect for tuning considerations.)

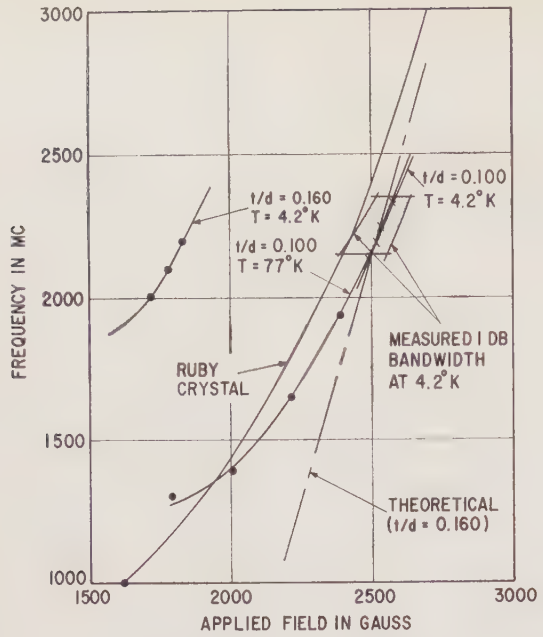


Fig. 8—Resonant frequency vs applied magnetic field for YIG ferrite disks at 77° K and 4.2° K.

TABLE I
YIG Isolator Characteristics at 4.2°K

Frequency (Mc)	Forward Loss (db)	Reverse Loss (db)	Figure of Merit
2100	3.3	90	27.3
2150	3.5	102	29.1
2200	3.4	106	31.2
2250	3.6	106	29.5
2300	3.4	103	30.3
2350	3.7	117	31.6

A set of experiments determined the magnitudes of the forward and reverse magnetic loss at 4.2°K. The resulting data are given in Table I, and indicate clearly that the reverse loss across the 2120- to 2380-Mc operating band is greater than 100 db (which is sufficient to operate a 50-db gain maser with short-circuit stability). The figure of merit of the isolator disks is about 30. (This is about half of the measured figure of merit at room temperature.)

III. Maser Operation

A. General Description

The optimum operating parameters of a maser, such as the relationship of the signal frequency, the pump frequency and the external magnetic field required to obtain maser operation, depend upon the quantum mechanical properties (energy levels, RF transition probability and relaxation times) of the paramagnetic crystal. These quantum mechanical properties are strongly dependent upon the magnitude of the external magnetic field and its angular orientation θ, with respect to the crystal C axis. All of the experiments performed used ruby (Cr^{+++} in Al_2O_3), with the C axis oriented at 90° with respect to the external magnetic field. Fig. 9 is the energy level diagram for a 90° oriented ruby, and shows four low-lying energy levels since ruby has a spin of $S=3/2$. The signal and pump transitions used are between energy levels (1-2) and (1-3), respectively. The 90° orientation was used because it yields the lowest magnetic Q, and hence the greatest maser gain per unit length. This low magnetic Q is obtained because of the unique combination of high RF signal transition probability and high inversion ratio.

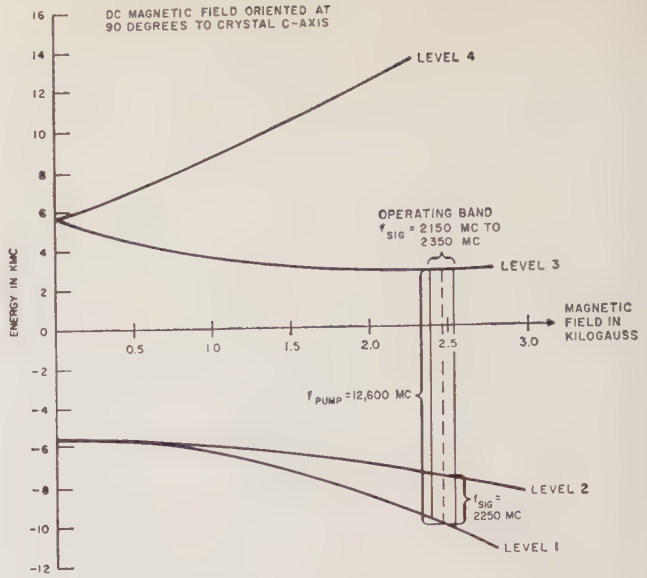


Fig. 9—Energy level diagram of 90° oriented ruby maser.

A discussion of the methods used to realize the low available magnetic Q and other factors that maximize the maser gain per unit length follows.

B. Maser Gain per Unit Length

Once the slowing factor S of the slow-wave structure has been adjusted to a maximum (upper limit set by bandwidth considerations), the maser gain can be increased in two ways:

1) Maximizing the ratio of the filling factor to the magnetic Q,
2) Increasing the structure length.

The simplest technique is to increase the structure length. However, this is not very desirable since the longer the structure the larger and heavier the electromagnet that supplies the external magnetic field must be. The more advantageous technique is to first maximize the gain per unit length and then adjust the overall length to obtain the proper gain.

1) *Optimum Ruby Loading of Comb Structure, and C Axis Orientation with Respect to RF Fields*

In Section IID, it was pointed out that the matrix elements of the RF signal transition are elliptically polarized, and become increasingly linearly polarized as the

frequency is decreased. The front-to-back ratio for a circularly polarized field was about 4:1 in the 2120- to 2380-Mc region. Consequently, if active ruby crystal is placed completely in the plane of circular polarization, one can achieve theoretically a 25 per cent increase in the gain per unit length by loading both sides of the comb structure with ruby [24], as compared to the conventional one-sided loading. In practice an improvement significantly greater than 25 per cent should be realized since the crystals are not completely contained in a single plane of circular polarization, but are distributed over a large region having different degrees of ellipticity. The degree of improvement obtained would be a function of frequency since the RF field distribution is frequency dependent. For example, as the RF magnetic fields approach the condition of linear polarization,[2] the gain in decibels obtained with two-sided loading approaches twice that which would be obtained with one-sided loading.

Since the square of the matrix element parallel to the C axis is about four times that of the perpendicular component, a considerable improvement should be obtained by aligning the C axis relative to the RF magnetic fields in a manner that maximizes the interaction—$(S \cdot H_{rf})^2_{max}$. Since the region of the ω-β diagram used for maser operation in our structure is near the lower β end (Fig. 2), the best crystal alignment is one in which the C axis is almost parallel to the direction of propagation [24]. (A crystal conforming to this alignment is here defined as a 0° crystal.) Use of a standard crystal would result in a C axis alignment of about 60° in relation to the direction of propagation. This is a result of the ruby crystal growth pattern. Fig. 10 shows the two crystal configurations, with their relative orientations with respect to the microwave structure geometry and magnetic fields.

The actual improvement that can be obtained by two-sided loading compared with one-sided loading, and 0° C axis orientation compared with 60° C axis orientation, is a function of the polarization seen by the ruby weighted by the square of the matrix elements, and the RF energy distribution across the crystal. A qualitative measure of the improvement that is expected has been obtained for the frequency range in the region of 2500 gauss by calculating $(S \cdot H_{rf})^2$ as a function of the average field ellipticity in the structure. (This calculation assumes that the α-direction cosine coefficient [19] is zero.) Fig. 11 is a plot of this calculation and shows that the 0° ruby is vastly superior to the 60° ruby for elliptical polarizations, where the major axis lies in the direction of propagation. The maximum improvement is obtained for a linearly polarized field, h_z, and decreases as circular polarization is approached. In addition, 0° two-sided loading yields improvements from a factor of about 1.25 for circular polarization to a factor of 2 for linear polarization. (It should be pointed out that this improvement multiplies the "db" gain factor.)

The two-sided loading results in reciprocal maser gain, necessitating a greater degree of isolator reverse loss to obtain short-circuit stability. However, this is no problem with the high figures of merit and the high susceptibilities obtainable with YIG (Table I).

Another interesting point is made in Fig. 11, and was mentioned in Section IID—that is, there is a polarization plane for the 0° crystal that yields an infinite front-to-back ratio. This occurs when the value of the ellipticity of the field polarization is the reciprocal of the ellipticity of the matrix elements—that is, $\langle h_z/h_y \rangle \approx 0.35$. Fig. 12 shows the square of the matrix elements for right- and left-hand field polarizations of a one-side loaded 0° ruby. Although it is possible to operate with an infinite front-to-back ratio, a high price would be paid in the magnitude of the forward gain because of the low matrix element acting on the forward wave. In addition, the magnitude of the reverse loss caused by a dark ruby would also be small because of poor interaction.

A series of experiments were performed to determine the difference in electronic gain that is obtained with a 0° and a 60° crystal C axis orientation (Table II). In the measurements, a slow-wave structure $1\frac{7}{8}$ in in length, operating in the 1800- to 2000-Mc region, was loaded on both sides, first with a set of 0° crystals and then with a set of 60° crystals; both crystals being of the same chromium concentration. The structure slowing factors measured for the 0° ruby loading was found to be 39 per cent greater than the 60° crystal. This was expected because of the nonisotropic dielectric constant of ruby, which varies from 9.5 to 12 depending upon the C axis orientation.

Table II shows that the 0° ruby does yield a considerable degree of improvement over the 60° ruby (from 45 to 67 per cent greater db of gain), because of its higher matrix element. In addition, the gain of the 0° ruby slightly decreases with increasing frequency, though the gain of the 60° ruby increases directly with frequency. This results in a decreasing gain improvement with increasing frequency as was expected (Fig. 11). The region of the ω-β diagram that was used in this structure was almost identical to the region used in the 2120- to 2380-Mc structure. Thus, the results apply qualitatively to the higher frequency.

This investigation resulted in the use of 0° ruby crystals in a two-sided loading configuration for the final slow-wave structure.

2) *Chromium Concentration of Ruby*

Several maser experiments were conducted using ruby with chromium concentrations of 0.065 and 0.125 per cent. These concentrations are considerably higher than the nominal 0.05 per cent used in most masers, and were expected to increase the relative signal absorp-

[2] For a forward wave comb structure, linear polarization is approached as the operating frequency approaches the lower cutoff frequency.

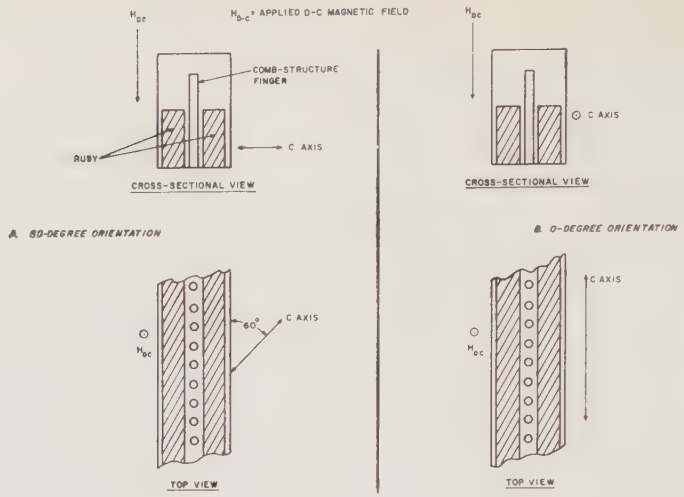


Fig. 10—*C*-axis orientations of ruby crystal with respect to comb structure.

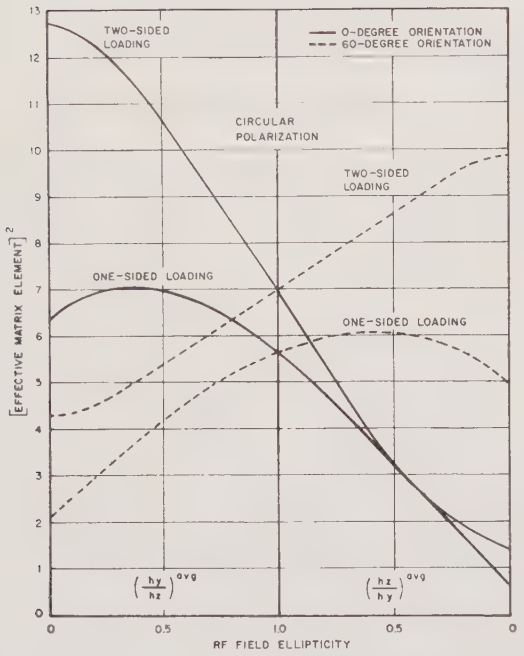


Fig. 11—Square of effective matrix elements as a function of magnetic field ellipticity and loading.

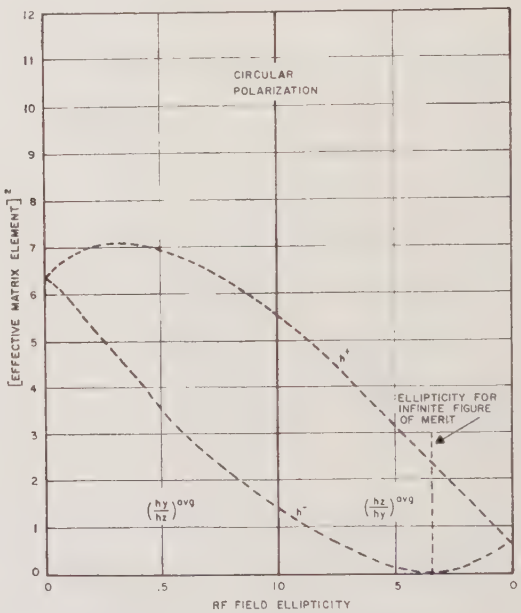


Fig. 12—Square of effective matrix elements of right- and left-hand elliptical polarizations for singly loaded 0° ruby crystal.

TABLE II

MASER GAIN CHARACTERISTICS FOR 0° AND 60° RUBY CRYSTALS

Frequency (Mc)	Bath Temperature (°K)	Electronic Gain of 60° Crystal (db)	Electronic Gain of 0° Crystal (db)	Adjusted* Gain of 0° Crystal (db)	Gain Ratio Improvement $\left(\frac{0° \text{ Adjusted}}{60°}\right)$
1800	1.8	4.25	9.8	7.1	1.67
1850	1.8	4.25	9.7	7.0	1.65
1900	1.8	4.50	9.3	6.7	1.49
1950	1.8	4.60	9.1	6.6	1.45

* The gain adjustment is made because of the greater structure slowing (39 per cent) of the 0° ruby. The ratio of the slowing factors was nearly constant across the 1800 to 2000 Mc region.

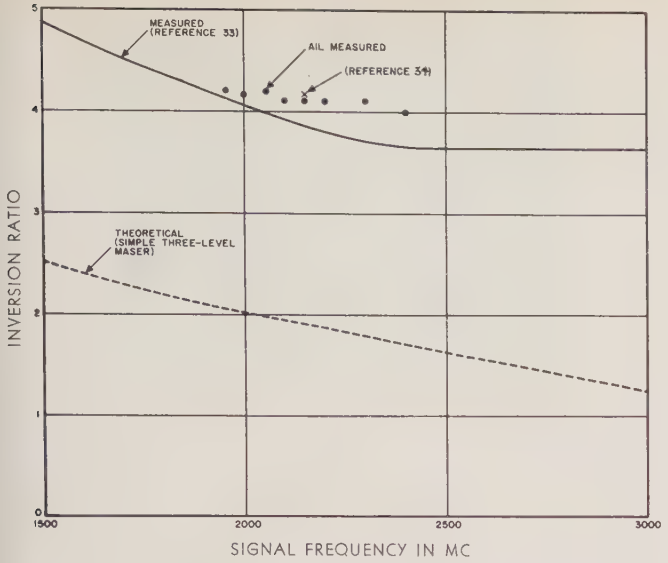


Fig. 13—Inversion ratio of ruby crystal as a function of frequency (for $\theta = 90°$).

tion by 25 and 70 per cent, respectively [25]. Assuming that the concentrations are low enough not to affect the inversion ratios[3] by cross-relaxation processes,[4] the maser gain per unit length should increase directly with the absorptions.

A series of inversion measurements were made on both crystals. It was not possible to obtain inversion in the 0.125 per cent crystal at 1.8°K or 4.2°K, because of the competing cross-relaxation effects as well as higher-order processes that destroy temperature differences in the spin system. However, inversion was obtained at 1.8°K on the 0.065 per cent crystal across the 1850 to 2350 Mc region. (Inversion measurements at 4.2°K did not show any change from the 1.8°K measurements.) Fig. 13 is a plot of these measurements compared with measurements made on a 0.05 per cent ruby [33], on a 0.06 per cent ruby [34], and theoretical values expected from a simple three-level maser system. All three independent measurements are in good agreement, but are considerably higher (greater than a factor of 2) than predicted by a simple three-level system. This anomalous behavior of the inversion ratio is believed to be caused by the shortening of the idler relaxation time due to a cross-relaxation effect that involves a four-spin flip process. The frequency relationship involved in the conservation of Zeeman energy is

$$f_p + f_{idl} = 2f_{3-4}. \tag{15}$$

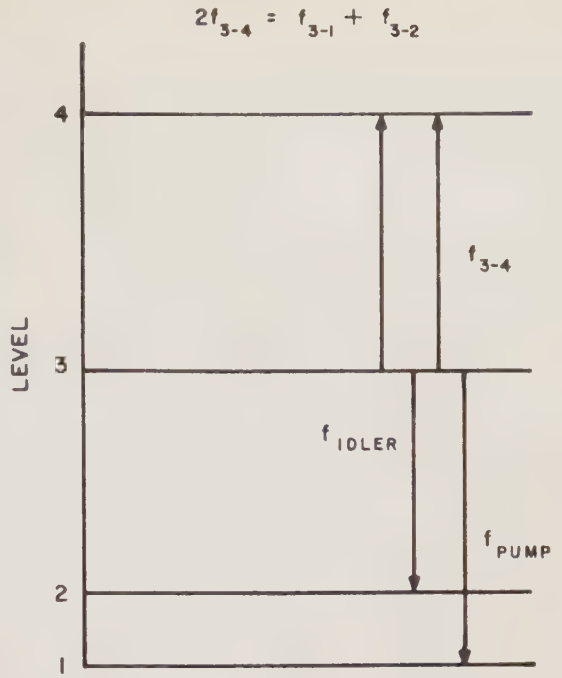


Fig. 14—Energy level diagram of four-level spin flip process in ruby crystal.

Fig. 14 is an energy level diagram illustrating the spin flip process; two spin flips from level 3-4 occur simultaneously with one spin flip from level 3-2 and one spin flip from level 3-1. The Zeeman energy gained by the 3-4 transition nearly equals the energy lost by the 3-1 and 3-2 transitions, thus nearly conserving the Zeeman energy. Roberts and Tenney [35] have obtained a solution to the rate equations for this mode of operation, and have given the following expression for the inversion ratio

$$R = \left(\frac{f_p}{f_s}\right)\left\{\frac{22 - \dfrac{50}{4P-3}}{19 - \dfrac{25}{4P-3}}\right\} - 1 \tag{16}$$

where

f_p = Pump frequency,
f_s = Signal frequency,
$P = W_c/w$ = Ratio of cross-relaxation transition probability (W_c) to thermal relaxation probability (w).

[3] The inversion ratio R is defined as [26]

$$R = \frac{T_b}{T_s} = \frac{1 - \left(\dfrac{\tau_s}{\tau_{idl}}\right)\left(\dfrac{f_{idl}}{f_s}\right)}{1 + \left(\dfrac{\tau_s}{\tau_{idl}}\right)}$$

where

T_s = Signal-frequency spin temperature,
T_b = Maser bath temperature,
τ_s = Spin-lattice relaxation time of signal transition
τ_{idl} = Spin-lattice relaxation time of idler transition,
f_{idl} = Idler frequency,
f_s = Signal frequency.

[4] The cross-relaxation process [27]–[32] involves the direct exchange of energy between neighboring paramagnetic ions; the spin-lattice relaxation involves an energy exchange between the paramagnetic ions and the lattice vibrations. Bloembergen [27] has shown that the probability of a cross-relaxation process occurring is high if the conservation of Zeeman energy in the spin system is satisfied to within a few line widths. Consequently, since the probability is proportional to the proximity of the spins, it would be expected to be dependent upon concentration.

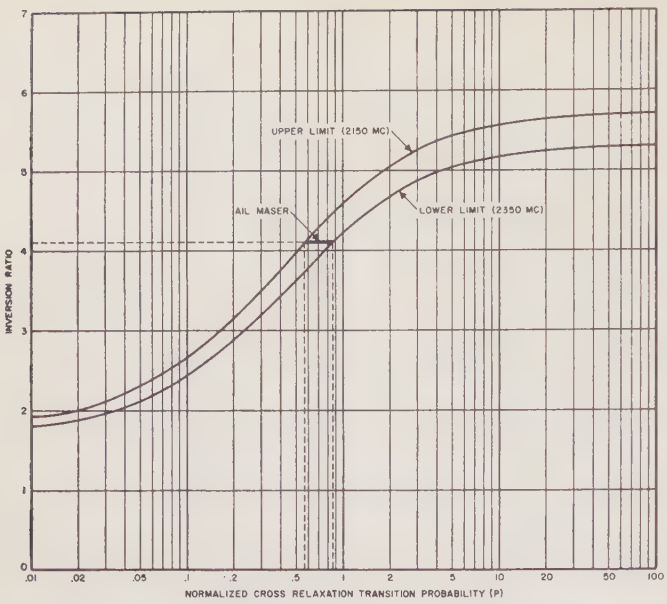


Fig. 15—Calculated inversion ratios of four-level spin flip process.

This equation has been plotted in Fig. 15 for signal frequencies of 2120 and 2380 Mc, as a function of W_c/w. This curve shows that

1) As $W_c \rightarrow 0$, $R \rightarrow$ the values predicted by the simple three-level system (Fig. 13),
2) As $W_c \rightarrow \infty$, $R \rightarrow$ a value greater than 5.7.

To obtain the magnitude of inversion ratios measured, W_c/w must be about 0.55 and 0.85 for the 2120 and 2380 Mc signal frequencies. It is believed that these values are reasonable because the Zeeman energy in the spin system is conserved to within about 4 line widths at 2380 Mc and about 6 line widths at 2120 Mc.

To further investigate the cross-relaxation effect, a series of maser gain recovery measurements were made on a full-length maser structure having about 30 db of gain. It has been shown [30] that a transition involved in a cross-relaxation process will have a recovery characteristic, after being saturated by a high-level pulse, that is represented by two or more relaxation times. If the saturating pulse is short compared to the cross-relaxation time, these multiple time constants can be observed. Fig. 16 is a typical photograph of the recovery time of the maser, operating at a bath temperature of 1.8°K, after being saturated by a 3-msec high-power pulse. The actual recovery times are obtained by plotting the data on semi-log paper and determining the slopes (Fig. 17). It appears that the recovery process is described by three relaxation times, two of which are easily determined to be about 90 msec and 270 msec. The third relaxation time is estimated to be about 5 msec.

C. Maser Gain and Instantaneous Bandwidth

Following the evaluation of maser operation as a function of C axis orientation, loading, and chromium

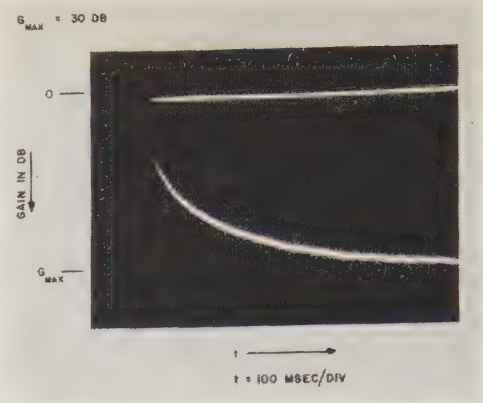


Fig. 16—Recovery time of TWM.

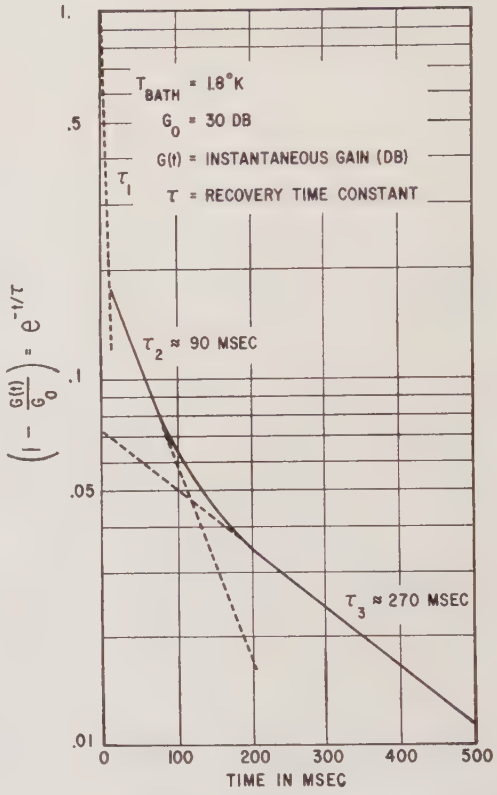


Fig. 17—Recovery time of TWM showing multiple relaxation times.

concentration, a series of gain and bandwidth measurements were made across the 2120 to 2380 Mc frequency band. The final slow-wave structure configuration used in these measurements consisted of a comb that was loaded on both sides with 0° X-ray oriented ruby (C axis oriented in a plane parallel to the direction of propagation), and on one side with polycrystalline YIG isolator disks. The active length of the ruby was $6\frac{1}{2}$ in, having a chromium concentration of 0.065 per cent. Fig. 18 is a photograph of the slow-wave structure assembly. The comb is folded in half; the two sections lie side by side having a common wall and are connected in series by means of a small section of coaxial cable. This was done to minimize the size and weight of the magnet needed

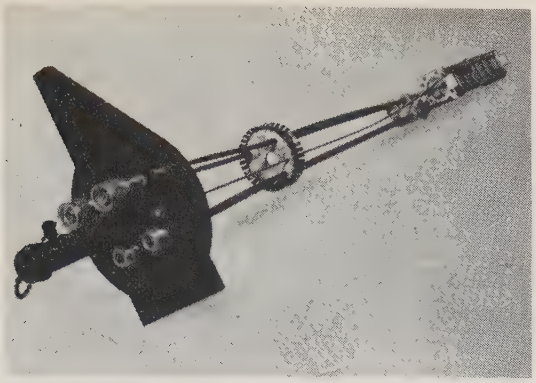


Fig. 18—TWM structure.

TABLE III
TWM Gain Performance

Signal Frequency (Mc)	Net Gain at 1.8°K (db)	Net Gain at 4.2°K (db)	Pump Frequency (kMc)	Magnetic Field (gauss)
2125	21.0	—	—	—
2150	30.0	11.1	12.48	2395
2175	31.0	—	—	—
2200	29.5	11.0	12.53	2420
2225	28.5	—	—	—
2250	30.0	11.4	12.61	2445
2300	28.0	10.4	12.70	2470
2325	28.0	—	—	—
2350	27.0	10.0	12.79	2495
2375	13.0	—	—	—

to give the high degree of field homogeneity necessary for high gain.

Table III gives the measurements of the net maser gain made at liquid-helium bath temperatures of 4.2°K and 1.8°K, along with the associated pump frequencies and magnetic fields.

Table III makes it clear that the gain data taken at 1.8°K is 1) nearly constant across the tuning range, being close to 30 db, and 2) has no regenerative effects in the tuning band. These desirable characteristics are caused by the high degree of reverse isolation (about 100 db) that was obtained with the polycrystalline YIG disks. In addition, the net gain at 1.8°K is about 2.8 times greater than the net gain at 4.2°K. Comparing the electronic gains (total circuit losses shown in Fig. 4 plus the net gains of Table III) that are obtained at the two operating bath temperatures, it can be seen that they correlate well with that predicted by the bath temperature ratio.

All of the data shown in Table III was obtained by electronically tuning the maser with a single frequency-calibrated dial that simultaneously adjusted the pump frequency (delay-line voltage of a BWO) and magnetic field (current through an electromagnet). No mechanical tuning was necessary because of a multiple resonance effect in the structure supporting the pump frequency. The amount of pump power required for saturation was about 100 mw.

It was found that the maser gain was not a critical function of the pump frequency. Furthermore, the signal frequency, when being pumped with a fixed CW frequency, could be tuned about 120 Mc before a 3-db gain degradation was observed (Fig. 19). This wing saturation effect is desirable because it eases tracking of the pump frequency and magnetic field when tuning the maser.

Fig. 20 is a plot of a typical instantaneous bandwidth curve measured at 2189 Mc. There is a slight hump on the high-frequency side of the amplification band. Furthermore, the measured bandwidth is slightly greater than predicted by the nominal 20-oersted ruby line width, operating at 30-db gain. These are the results of a slight stagger-tuning effect caused by slight

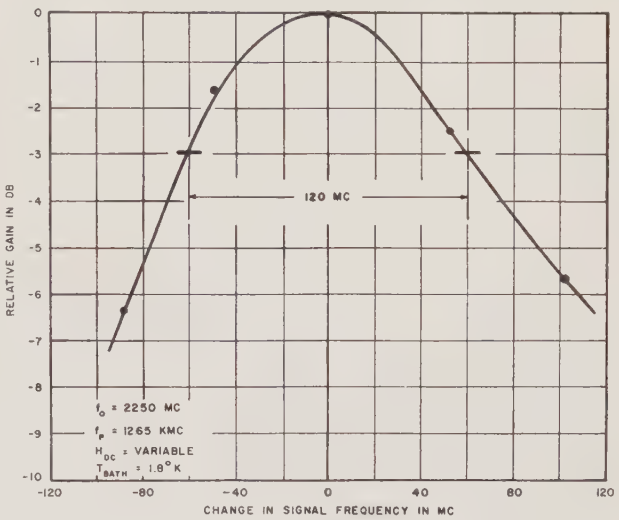


Fig. 19—Gain vs change in signal frequency for fixed pump frequency and optimized magnetic field.

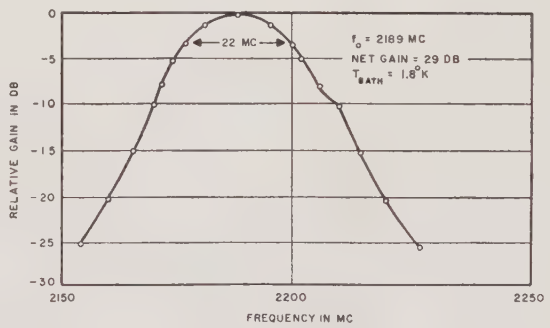


Fig. 20—Instantaneous bandwidth of TWM.

variations in the relative C axis orientations of the four ruby slabs that were used.

Several experiments were performed in which an attempt was made to produce amplification bandwidths in excess of the line width of the material. Bandwidths in excess of 125 Mc were obtained with electronic gains of 16.5 db by stagger-tuning the applied magnetic field [36].

Fig. 21 shows photographs of oscilloscope displays of the maser bandwidth under increasing staggered field conditions. The field staggering was accomplished by

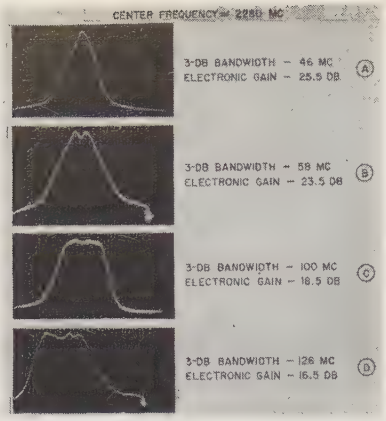


Fig. 21—Oscilloscope display of maser amplification bandwidth under different field-staggering conditions.

periodically shimming one of the pole pieces of an electromagnet with thin rectangular slabs of high-permeability material.

IV. System Performance

A. General Description

The maser amplifier can easily be tuned to any operating frequency in the 2120- to 2380-Mc band by simply adjusting a single frequency-calibrated dial. This dial simultaneously sets the external magnetic field (current through an electromagnet) and pump frequency (delay line voltage of a BWO) to the proper value. By using the calibrated dial, the amplification frequency can easily be set to within ± 3 Mc of the desired signal. This is sufficiently accurate for most applications since the maser instantaneous bandwidth is about 22 Mc.

If a more accurate frequency setting is required, a mirrored scale ammeter, located on the front panel of the power supply, can be used to tune the maser to within ± 0.5 Mc of the desired frequency. The ammeter reads the current through the electromagnet thus setting the magnitude of the external magnetic field to the proper value. The magnetic field is the only critical adjustment since the pump frequency may deviate considerably from the required values (Fig. 19).

B. Important Characteristics

1) Receiver Noise Temperature

Measurements of the over-all maser receiver input noise temperature T_e were made using an AIL Type 70 Hot-Cold Body Standard Noise Generator in a Y-factor measurement. The hot and cold loads of the noise generator were at boiling-water and liquid-nitrogen temperatures, respectively.

A series of 10 separate measurements was made at each of 10 different frequencies across the amplifier tuning band; the results of these measurements are shown in Table IV.

Table IV shows that T_m varies ± 2.1°K across the band, being as low as 9.2°K at 2280 Mc. This minimum

TABLE IV

Results of Receiver Noise Temperature Measurements*

Signal (Mc)	Net Maser Gain (db)	T_e(°K)	T_2(°K)	T_m(°K)
2170	31	12.4	2420	10.5
2200	29.5	13.5	2345	10.9
2220	28	15.8	2290	12.2
2230	29	15.1	2420	12.0
2250	30	15.5	2050	13.4
2270	28	15.4	2345	11.7
2280	28	12.8	2295	9.2
2300	28	13.6	2350	9.9
2330	27.5	14.3	2350	10.1
2350	27	15.1	2520	10.1

* All of the noise temperatures tabulated are average values.
T_e = Over-all receiver noise temperature including second-stage noise contributions (measured data). We were able to measure T_e to within ± 2°K because of the high degree of stability of the maser.
T_2 = Second-stage noise temperature (measured data).
T_m = Maser noise temperature including feed-line losses (calculated from T_e and T_2).

is considerably greater than the maser spin temperature, which is less than 1°K (determined from inversion measurements). There are two main contributing noise sources responsible for the temperature degradation.

1) The dissipative losses of the coaxial input feed line, which is located in the helium bath, and which was designed to be as short as possible with as large a diameter as possible, consistent with keeping the cryogenic heat conduction losses low. The dissipative loss of the feed line measured at 290°K was about 0.2 db. The actual noise contribution caused by this loss was not accurately known because of the temperature gradient on the feed line.
2) The noise contributed by the dissipative losses of the slow-wave structure. The magnitude of this contribution depends upon the ratio of the gain-per-unit length to the loss-per-unit length of the structure, and the temperature of these losses. The contribution caused by this mechanism is small compared to feed-line losses.

It is believed that these losses can be further decreased, thus yielding maser system noise temperatures closer to the spin temperature.

2) Maser Gain Saturation and Dynamic Range

A series of gain saturation measurements was made on the maser under three different input signal conditions.

1) Continuous wave,
2) Pulsed (duty cycle = 0.1, pulse width = 100 μsec),
3) Pulsed (duty cycle = 0.01, pulse width = 100 μsec).

Fig. 22 plots the results of these measurements, and shows that the maser input power saturation level (defined as the power required to decrease the gain by 3 db) increases with decreasing duty cycle—that is, -54 dbm, -44 dbm and -34 dbm for the signals 1), 2) and 3) above. The resulting dynamic ranges (for a 1-Mc post-receiver

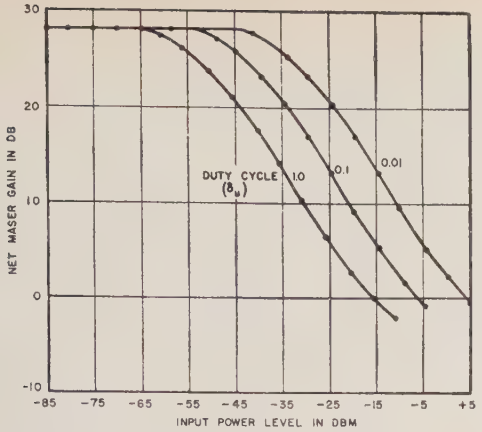


Fig. 22—TWM gain saturation vs input signal power as a function of duty cycle.

bandwidth) are 75 db, 85 db and 95 db. The increase in pulse saturation power is caused by the long spin storage time of the ruby, and is effective for pulse signals that are short with respect to it. The spin-lattice relaxation time T_1 of ruby is in the hundreds of milliseconds, which is quite long compared to the pulse width generally used in high-resolution systems.

The saturation output power of the maser is a constant. Thus, if the system saturation measurements were made with lower maser gains, the level of input power causing saturation would increase, resulting in greater dynamic ranges.

3) Recovery Time

Fig. 16 is a photograph of the recovery time of the maser, after being saturated with a 3-msec high power pulse. The actual recovery times were determined by the plot shown in Fig. 17. The recovery process is described by several relaxation times, caused by a four-level spin-flip cross-relaxation mechanism. The time required for the maser to recover to within 3 db of its presaturated gain is about 50 msec. Hence, one can see the added advantage of a relatively fast recovery time in addition to the greater inversion ratios that can be obtained with the cross-relaxation mechanism.

Furthermore, marked improvements in recovery time might be obtained in future masers by impurity-doping of the idler transition of the ruby to reduce the idler relaxation time. (This was done in the cerium-doped gadolinium ethyl sulfate maser [13].) In addition, the proper use of low power level ferrimagnetic limiters, with the masers should yield rapid recovery times.

4) Gain Stability

Several gain stability measurements at a helium bath temperature of 1.8°K, and a maser gain of 30 db, yielded a long-term peak-to-peak drift of ± 0.1 db and a short-term peak-to-peak stability of better than ± 0.05 db over a period of several hours. Fig. 23 is a photograph of the output of a recorder from a typical stability run of one hour. The fluctuations represent the instabilities of a complete maser IF receiver, fed by a standard signal generator. Thus, a significant portion of the variation must be ascribed to the measurement technique rather than the maser.

The parameter that was considered to have the greatest effect on the maser long-term stability was the magnet, since the field stability must be considerably better than the magnetic line width of the ruby (which is less than 1 per cent of the external magnetic field). To minimize this problem, the magnet design consisted of a permanent magnet with a pair of "tickler" coils to give the necessary field variation required for tuning. This technique made it possible to use a relatively small current regulated power supply, and minimized coil-heating problems.

5) Signal Desensitization

Fig. 24 shows the gain saturation effect (desensitization) of nearby interfering signals. The power level of the interfering signal required to decrease the maser gain by 3 db at its center frequency is plotted as a function of the interfering signal. The shape of the measured response closely follows the maser amplification characteristic. Fig. 25 is a block diagram of the test setup used for the measurements. The filter, which is located between the maser and the second-stage amplifier, insured that the interference effect measured was caused by the maser and not the second stage. In addition, to give added isolation, the interference signal was CW, while the probing signal was square-wave modulated, detected, and amplified at 1000 cps.

6) Environmental Tests

The maser amplifier was subjected to an environmental testing program in accordance with MIL-E-4158. The tests included in this program were as follows:

1) High-altitude storage (40,000 ft),
2) High-altitude operating (10,000 ft),
3) Low-temperature storage (−80°F),
4) Low-temperature operating (−20°F),
5) High-temperature storage and operating (160°F),
6) Humidity (seven cycles),
7) Rain,
8) Salt spray,
9) Sand and dust,
10) Radio interference,
11) Shock,
12) Vibration.

The units successfully passed all tests. However, the resonance phase of the vibration tests on the vacuum pump and power supply had to be modified for the vertical plane. The low-frequency amplitude to which these two units were subjected had to be decreased to about one-half the specified value because of bottoming of the shock mounts.

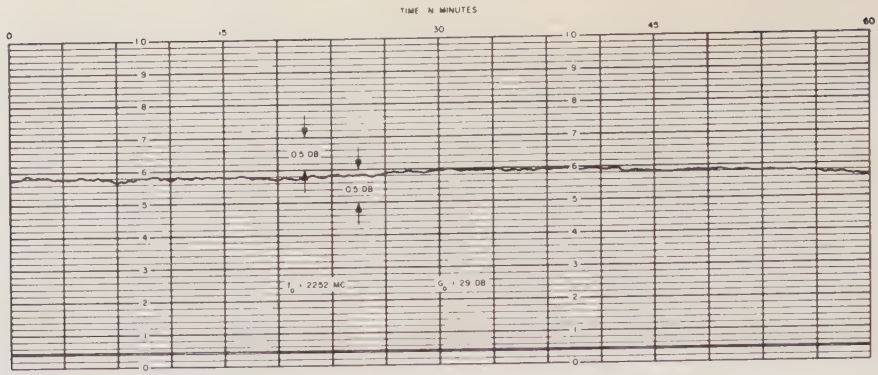


Fig. 23—Recorder display of gain stability for TWM.

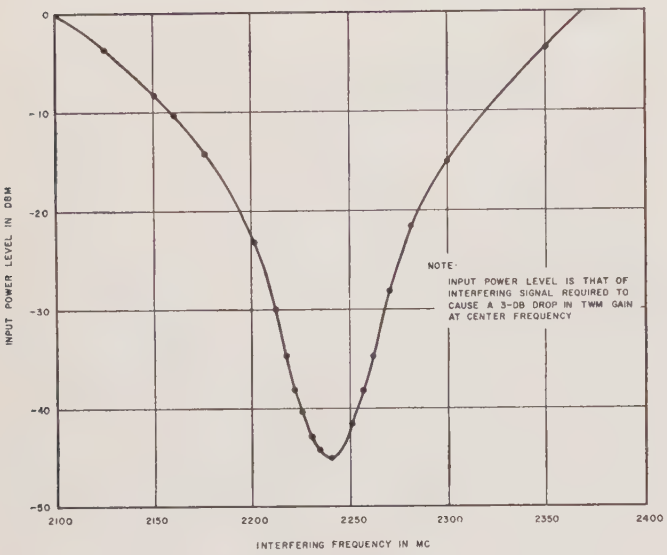


Fig. 24—TWM gain desensitization as a function of nearby interference signal.

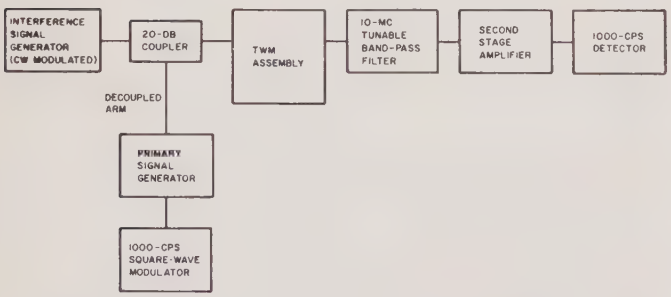
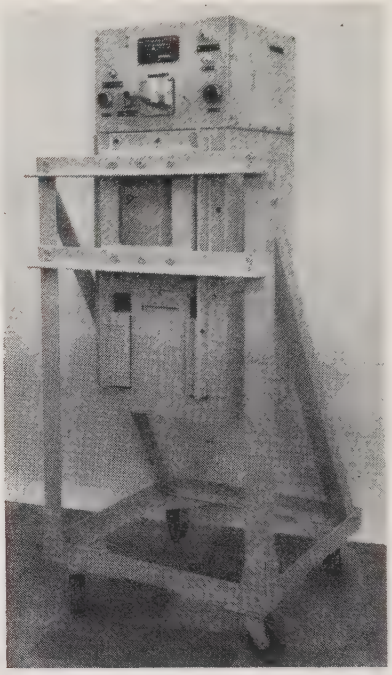


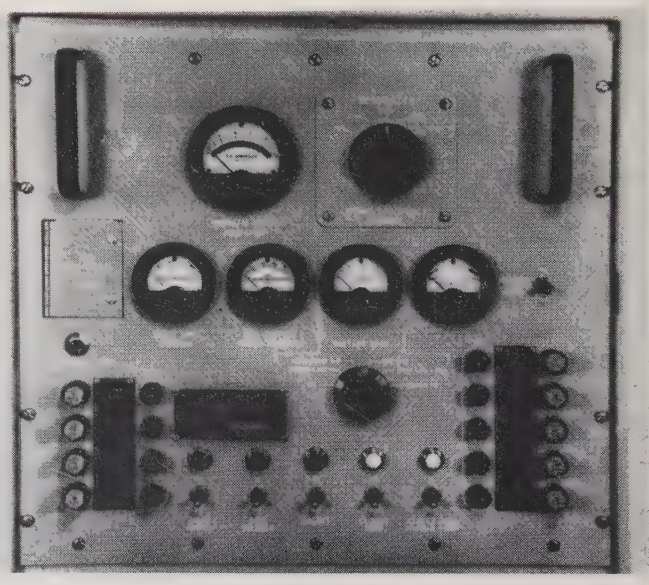
Fig. 25—Test setup used to measure maser gain desensitization.

7) *Package Description*

The over-all system consists of three units—1) the TWM assembly, 2) the remote-control power supply and 3) the vacuum pump. These units can be separated by as much as 100 feet to permit the TWM assembly to be mounted as close to the antenna feed as practicable. A photograph of the packaged TWM assembly and the remote control power supply is shown in Figs. 26(a) and (b), respectively.



(a)



(b)

Fig. 26—Packaged units of TWM system. (a) TWM assembly. (b) Remote-control power supply.

V. Conclusions

This report has described a TWM receiving system that has low noise, high gains with large instantaneous bandwidths and ease of tuning over a greater than 11 per cent band. The system has been subjected to a rigorous environmental testing program that has proved its inherent ruggedness and stability. This truly takes the maser out of the laboratory and makes it available for military field applications.

The logistic problem of the cryogenic charging fluids must still be considered insurmountable for some applications, such as airborne use or operation in remote geographical areas where the refrigerants are not readily available. However, a considerable effort is being placed on miniaturized, reliable closed-cycle refrigerating systems within the cryogenics field. Furthermore, it is believed that such closed systems, having a high degree of reliability and long-time trouble free operation, will be available in the near future.

In future systems, a weight reduction in the assembly containing the TWM structure is desirable to facilitate mounting problems, and make possible airborne application. The magnet is the major portion of the weight of this assembly (110 pounds), and work now in progress on the feasibility of replacing the heavy magnet assembly with a 3-pound superconducting magnet is proving successful. This work will be reported at a later date. In maser applications where the magnetic field is not too high, niobium wire can successfully be used [37]. At the higher frequencies, where the magnitude of the magnetic fields required increases, the newly discovered high-field high-current-density super-conducting materials such as Nb_3Sn [38] and NbZr [39] can be used.

With the successful application of closed cryogenic systems and superconducting magnets, the maser will unquestionably be a practical lightweight low-noise amplifier for all types of applications including airborne.

Acknowledgment

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Oscillators by Means of Magnetoresistance Effect*

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Summary—This paper describes the application of the magnetoresistance effect to oscillators using the high mobility semiconducting compound InSb as the active element. The first stable oscillator consisted of an InSb Corbino disk in a ferrite pot core reduced to a temperature of −40°C. The frequency was 210 cps and the open-circuited ac voltage was 540 mv, peak to peak.

In order to construct a stable oscillator at room temperature, the shape of the semiconductor specimen was modified to a rectangular form composed of narrow strips of InSb joined together with metallic indium. This specimen has a comparatively higher internal resistance and a more pronounced magnetoresistance effect at low magnetic flux densities. A second oscillator using this specimen as an active element in an *E*-form ferrite core was tested and found to operate stably at a temperature of 25°C, in a frequency range from a few cps up to 300 cps. The maximum output power available was 2.5 mw, at 70 cps. There is no heating-up time required by the oscillator and the oscillation can start immediately under certain initial conditions.

The elimination of the equipment to provide the low temperature, *i.e.*, below 0° C for the oscillator has shown that the magnetoresistance effect can be made good use of in electronic devices without requiring a complicated circuit arrangement.

Introduction

SINCE THE introduction of the new semiconducting materials of III-V compounds,[1] much interest has been stimulated in the application of the Hall effect and the magnetoresistance effect to electronic devices. In previous publications,[2,3] amplifiers and oscillators utilizing the Hall effect were analyzed and described in detail, where indium antimonide or indium arsenide was used as the active element. Amplifiers and oscillators utilizing the magnetoresistance effect have been investigated and recorded elsewhere, but the material used was mainly bismuth and the operating temperature was within the range of liquid air and liquid hydrogen.[4] If indium antimonide or indium arsenide is chosen to construct the magnetoresistance oscillator, it should be possible to operate at room temperature.

Theoretical Consideration of the Oscillator

The magnetoresistance effect of a semiconductor specimen is very much dependent on the mobility of the carrier in the semiconductor and the shape of the probe. Since the mobility of the carrier usually varies with the temperature, the magnetoresistance effect of a given semiconductor can easily be adjusted by controlling the temperature or shaping the probe. As illustrated by Fig. 1, taken from Welker,[5] the most favorable shape of the specimen is that of a Corbino disk which consists of a thin probe of circular form with one contact joined to the center and the other contact around the circumference. With rectangular shapes, the magnetoresistance is dictated by the ratio of the length to the width of the specimen, a short and broad sample [Fig. 1(c)] having a more pronounced effect than a long and narrow one [Fig. 1(a)]. At small flux density, the change of the resistance is approximately proportional to the first power of the corresponding increment of the flux density. When the specimen is in the air gap of a small ferromagnetic core, which is energized by passing current through the exciting winding of a given number of turns to form a magnetoresistance unit, the value of resistance can be expressed in terms of the exciting magnetomotive force or the exciting current. Because of saturation of the ferromagnetic core, the top part of this resistance curve would be flattened (Fig. 2). This curve will be used for the analysis of the oscillator, with the assumption that the hysteresis loop is very small.

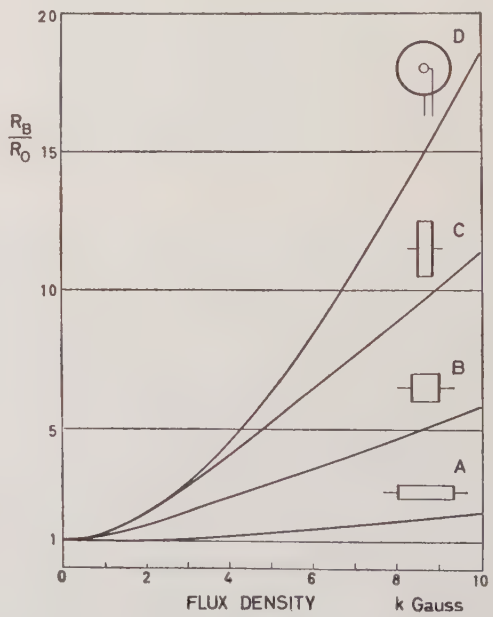

Fig. 1—The relative resistance change in the magnetic field due to different geometrical form. R_B is the resistance in the magnetic field and R_0 is the resistance at zero flux density.

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Fundamentally, an oscillator can only be built under the condition that an amplifier with feedback arrangement is possible, and the feedback can be made equal to or larger than unity. The arrangement of a magnetoresistance feedback amplifier is to have its output voltage, *i.e.*, the potential difference between the contacts of the magnetoresistance element, fed back to the exciting winding of the magnetic core (See Fig. 3.) In consideration of the magnetoresistance oscillator, the output power of the feedback amplifier should be sufficiently large to overcome the losses in the resonant circuit. With a semiconductor material of high mobility as the active element, the efficiency of the device may be high, but the power output is small. In order to keep the losses of the resonant circuit to a minimum, the choice of the core material, the core form and the length of the air gap is important. Ferrite material is suitable for this purpose because of its high specific resistance, high initial permeability and the air gap that can readily be made to the tenth of a millimeter with an accuracy of a hundredth of a millimeter. The disadvantage is that the low saturation of the ferrite core limits the output voltage growth.

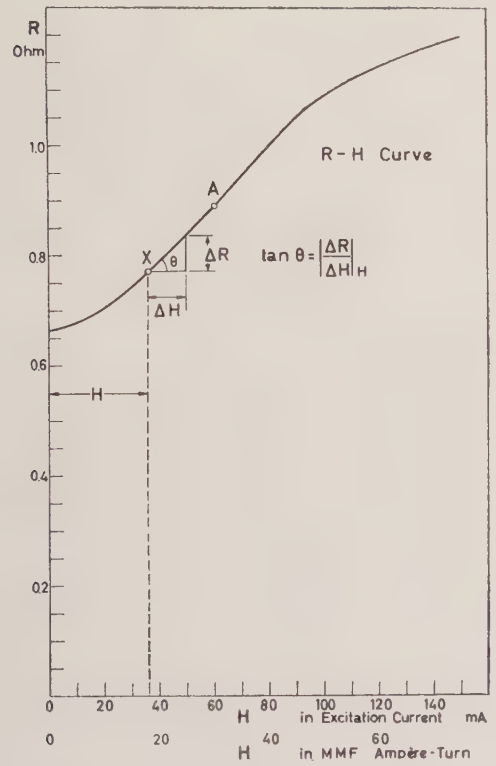


Fig. 2—The typical characteristic curve of a magnetoresistance effect unit.

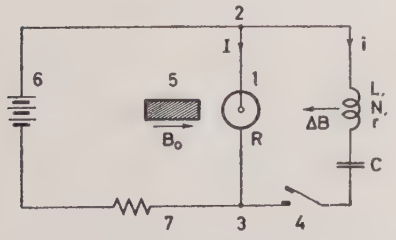


Fig. 3—The simplest circuit for the magnetoresistance oscillator with permanent magnet 5 to provide the bias field B_0. This circuit can also be used for the feedback amplifier if the condenser C is short-circuited.

Referring to the typical magnetoresistance curve given in Fig. 2, the slope, tangent θ, of the curve at any point x represents the rate of change of resistance per unit field intensity at that bias field

$$\left|\frac{\Delta R}{\Delta H}\right|_H$$

which is proportional to the change of the resistance per unit flux density, namely:

$$\tan\theta = \left|\frac{\Delta R}{\Delta H}\right|_H = \left|\frac{\Delta R}{\Delta B}\right|_B \cdot \mu = \mu m \tag{1a}$$

where

$$m = \left|\frac{\Delta R}{\Delta B}\right|_B \tag{1b}$$

and

μ = the incremental permeability, the slope of the $B - H$ curve at the quiescent point.

This tangent θ has a maximum value at a point A (inflection point) and in the neighborhood of this point the curve is approximately linear. Taking any point within this linear region as the quiescent point, the magnetoresistance can be expressed in a simple equation of linear form in terms of small incremental flux density as well as small incremental field intensity, as follows:

$$R = R_H + m\Delta B \tag{2a}$$

$$= R_H + \mu m \Delta H, \tag{2b}$$

with

R = the resistance of the semiconductor at any flux density,
R_H = the resistance of the semiconductor at the quiescent point,
ΔB = the incremental flux density,
ΔH = the incremental field intensity and
μ = the incremental permeability at the quiescent point.

For most cases, this permeability μ can be replaced by the permeability of air μ_0, provided that the core is well under saturation and the reluctance in that part of magnetic path in the ferromagnetic material is negligibly small in comparison with that in the air gap. With a constant control current I passing through the semi-

conductor, the voltage drop across the specimen is

$$IR = IR_H + I\mu m\Delta H \tag{3}$$

and the incremental voltage drop is

$$IR - IR_H = I\Delta R = I\mu m\Delta H. \tag{4}$$

If this voltage drop is used to feedback additively to the magnetic field, (see Fig. 3), the field intensity can be increased by an amount given by

$$\Delta H' = \frac{Ni}{g} = \frac{N}{g}\frac{I\Delta R}{R_H + r} \tag{5}$$

where

N = the number of turns of the feedback winding,
r = the resistance of the winding,
g = the effective length of the air gap and
i = the feedback current in the feedback winding $= I\Delta R/(R_H+r)$.

The incremental voltage drop of the semiconductor specimen will finally become

$$I\Delta R = \mu mI(\Delta H + \Delta H'), \tag{6}$$

or

$$I\Delta R = \frac{\mu mI\Delta H}{1 - KI} \tag{7}$$

where we may call

$$K = \text{the dc feedback factor} = (N\mu m)/g(R_H + r), \tag{8}$$

as it is only applicable in a magnetoresistance feedback amplifier for dc signals or slowly varying ac signals.

If the feedback KI is sufficiently large so that $KI = 1$, oscillation can occur. There are several parameters in the feedback factor that can be adjusted to yield large K values, such as

1) the air gap g that should be as small as possible,
2) the ratio of $N/(R_H+r)$ and
3) the factor m that should be as large as possible.

The minimum air gap is limited by the minimum thickness of the semiconductor specimen which is limited by technical considerations. The ratio of $N/(R_H+r)$ is fixed by the core form and the winding space available. Since the output power from a magnetoresistance specimen is very small, one has to make use of the maximum available power from the specimen for the feedback circuit, which means that the resistance of the semiconductor at the quiescent point R_H should be matched to the resistance of the winding r. The last parameter that can be adjusted is the factor m, which is dependent upon the initial resistance, the carrier mobility, the geometrical form of the specimen and the position of the quiescent point on the magnetoresistance curve.

To increase the feedback one can also increase the control current. The maximum control current is determined by how effective a heat-sink can be made for the specimen to prevent it from being unduly heated.

To prove mathematically that oscillations are possible, one can proceed quite straightforwardly. Taking the simple circuit as shown in Fig. 3, the semiconductor specimen 1 is under the influence of a constant magnetic field of flux density B_0 (from any kind of source, such as a permanent magnet 5 or a field coil) and has a resistance R_H corresponding to this flux density. A constant control current I is supplied by a dc source 6 to the semiconductor through a series resistance 7 and causes a voltage drop IR_H between the terminals 2 and 3. In addition to the constant magnetic field, the semiconductor will be subjected to a magnetic field excited by a winding of inductance L, resistance r and number of turns N. One end of the field winding is joined to the terminal 2 of the specimen 1, and the other end is connected in series with a condenser of capacity C, a switch 4 and finally joined to the terminal 3. At the moment $t=0$, switch 4 is closed, a surge current i will flow through the RLC loop. This energizes the field winding to induce a magnetic field of flux density ΔB that will act upon the semiconductor 1 to cause a small fluctuation in the resistance of the semiconductor specimen equal to

$$\Delta R = m\Delta B = \mu m\Delta H = \mu m\frac{Ni}{g}. \tag{9}$$

Neglecting for the moment the iron losses in the core, the relation between the voltage drop across the specimen 1, and the surge current i can be expressed as follows:

$$I(R_H + \Delta R) = L\frac{di}{dt} + (R_H + r)i + \frac{1}{C}\int idt, \tag{10}$$

where the positive sign in front of ΔR denotes that the feedback is positive. Combining (9) and (10), one obtains

$$IR_H = L\frac{di}{dt} + \left(R_H + r - \frac{\mu mNI}{g}\right)i + \frac{1}{C}\int idt, \tag{11}$$

which is a second-order, first-degree linear differential equation, after it is differentiated with respect to time t. The complete solution of (11) is the sum of a complementary function and a particular integral, the latter being the steady-state current. Since this case involves a constant direct voltage IR_H on a condenser, the steady-state current is zero. Imposing the boundary conditions that when $t=0$, $i=0$; and when $t=0$, the initial charge on the condenser equal to Q, the solutions for the current i, for the ac voltage variation $I\Delta R$ across the semiconductor and for the voltage drop E_c across

the condenser can be found, respectively, as follows:

$$1) \quad i = \frac{1}{\omega L}\left(IR_H - \frac{Q}{C}\right)\epsilon^{-\alpha t}\sin \omega t, \tag{12}$$

$$2) \quad I\Delta R = I\frac{\mu m N}{g}\frac{1}{\omega L}\left(IR_H - \frac{Q}{C}\right)\epsilon^{-\alpha t}\sin \omega t, \tag{13}$$

and

$$3) \quad E_c = IR_H\left[1 - \frac{\omega_0}{\omega}\left(1 - \frac{Q}{CIR_H}\right)\epsilon^{-\alpha t}\sin(\omega t + \theta)\right], \tag{14}$$

where

ω = the angular velocity

$$= \left\{\frac{1}{LC} - \left[\frac{(R_H+r)(1-KI)}{2L}\right]^2\right\}^{1/2},$$

α = a real constant $= \dfrac{(R_H+r)(1-KI)}{2L}$,

ω_0 = the angular velocity at resonance $= \dfrac{1}{\sqrt{LC}}$,

θ = a phase angle $= \tan^{-1}(\omega/\alpha)$,

and K is the dc feedback factor as given in (8).

In reality, the term r in the equations should be replaced by a term consisting of $(r+r')$, in which r represents the copper loss in the field winding and r' represents an equivalent resistance corresponding to the iron losses of the magnetic core and the miscellaneous losses in the circuit, which is a function of the ac voltage. The necessary condition for oscillation is now that KI must be larger than one in order to take care of the loss resistance r'.

It is obvious from the solutions that whether or not the oscillation can be built up and remain stable depends primarily on the parameter α, which, in fact, does not stay constant but varies with time in accordance with the iron and the miscellaneous losses in the circuit represented by r'. One should write

$$\alpha = \frac{1}{2L}\left(R_H + r + r' - \mu m\frac{N}{g}I\right). \tag{15}$$

For stable oscillation the parameter α should vanish in which case the frequency of the oscillation equals the resonant frequency

$$f_0 = \frac{1}{2\pi\sqrt{LC}}. \tag{16}$$

The final amplitude of the open-circuit ac voltage is a function of the control current I and the value of the quiescent magnetic field. It will be limited by the losses in the oscillating circuit and by the saturation of the magnetic core and the initial resistance of the semiconductor specimen at zero flux density.

Experimental Trial of the Oscillator at Temperatures Below 0°C

Using indium antimonde as the active element, a magnetoresistance unit has been built with ferrite for the magnetic core. The specimen is a Corbino disk made of monocrystal material having an outside diameter of 8.0 mm and an inside diameter of 0.5 mm, a thickness of 0.11 mm and a resistance of 0.2 ohms at 23°C. The magnetic core is composed of ferrite pot core (Philips D 45/39) having an air gap of $g = 0.22$ mm and an exciting winding of $N = 240$ turns, $L = 19.6$ mh and $r = 0.35$ ohms at 23°C. At room temperature, 23°C, the magnetoresistance effect, illustrated by curve *a* of Fig. 4, is considerable, yet the value of the factor m is small even at the optimum quiescent point, and the available output power is insufficient to excite the resonant circuit because of the very low internal resistance of the specimen and the limited amount of control current. In order to obtain a higher value of m and a larger output power, the mobility was adjusted by cooling the whole unit down to −40°C, where the characteristics of the magnetoresistance effect are much improved, as shown in curve *c* of Fig. 4. At a quiescent point of $H = 31.8$ ampere-turns, corresponding to $B = 1800$ gauss, the opti-

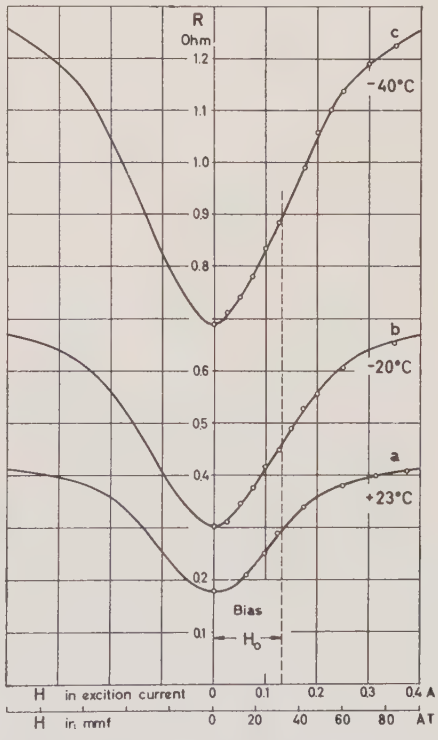


Fig. 4—The magnetoresistance characteristic of an InSb specimen in Corbino disk form and its dependence on the temperature.

mum value of m is given by

$$m = 0.011 \text{ ohm/ampere turn}$$
$$= 1.59 \times 10^{-4} \text{ ohm/gauss}$$

or

$$= 1.59 \frac{\text{meter}^2 \text{ ohm}}{\text{weber}},$$

and the feedback factor, in *mks* system, is now

$$K = \frac{\mu m N}{g(R_H + r)} = 1.67 \text{ per ampere.}$$

If the feedback should be equal to or exceeds unity to fulfill the condition of oscillation, the control current should have a minimum value of

$$I = 1/K = 1/1.67 = 0.60 \text{ A.}$$

With a suitable circuit, as illustrated by Fig. 5, the oscillation occurs and remains stable at a control current of 0.55 A and a quiescent point of about 32 ampere-turns. In Fig. 5, semiconductor specimen 1 is shown to be connected to a dc source 2 through a series resistance 3 and a choke coil 4. The specimen is under the influence of the magnetic field excited by a field winding 5 which serves as feedback winding as well as bias field winding. One end of the winding is joined directly to the specimen, and the other end through a condenser 6 and a switch 7 to complete the feedback circuit. To bias the field to the required quiescent point winding 5 draws current from the dc source 2 through a series connecting resistance 8 and a choke coil 9 of high inductance which prevents the ac from circulating outside the loop 1, 5, 6, & 7 of the resonant circuit so as to minimize the unnecessary losses of the oscillator. By use of a permanent magnet to bias the field to the required point the circuit becomes much simpler.

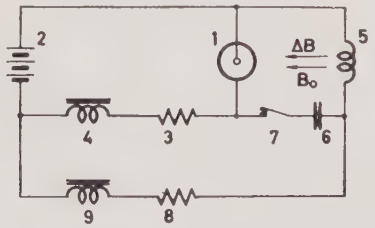


Fig. 5—The circuit for the magnetoresistance oscillator with a field winding 5 to provide the bias field B_0 as well as the feedback. This circuit is used for all experiments.

After the closing of the switch, the stable frequency of the oscillator is 210 cps which can be checked with the formula given in (13), using $L = 19.6$ mh and $C = 32$ μf, and is found to be within an accuracy of 5 per cent. The ac voltage between the contacts of the specimen is 540 mv peak to peak.

Experimental Trial of Oscillator at Room Temperature

A careful study on the performance of the last oscillator reveals that a high internal resistance and a large m of the semiconductor specimen are essential for the magnetoresistance oscillator. The Corbino disk has a more pronounced magnetoresistance effect than a specimen of any other shape, but it does not mean that its value of m is larger than that of the others. Besides, its very low internal resistance would permit only very small output power. A magnetoresistance specimen which has the same volume and thickness as a Corbino disk but in rectangular form could be made to have a resistance of 10 or more times larger than that of the Corbino disk. The magnetoresistance effect $\Delta R/R$ will be much smaller, because the specimen must be long and narrow in shape with the current flowing along the longitudinal direction (Fig. 1, curve A). This shortcoming can, however, be improved by shaping the specimen. Keeping the thickness unchanged, a long and narrow piece of semiconductor can be cut into several short and broad pieces which are joined together again with low resistive metal contacts. The total internal resistance will be almost equal to that of the original specimen, but the magnetoresistance effect will be near to that of a Corbino disk at a low magnetic flux density less than 4000 gauss. (See Fig. 1, curve C and D.) The result is that the internal resistance as well as the parameter m of this kind of specimen is much larger than that of a Corbino disk of the same thickness and volume.

These considerations have been tested with an InSb specimen of dimensions length = 8 mm, width = 4 mm, thickness = 0.12 mm, placed in the air gap of a ferrite magnetic core made of 2 E form (Philips 3 $E1$, D 42), with an air gap of 0.26 mm in the middle leg and a field winding of $N = 696$ turns, $r = 4.13$ ohms and $L = 160$ mh. The characteristic of the specimen is given in Fig. 6, curve A. The values of m and K at the optimum quiescent point of $H = 41.7$ ampere-turns and $B = 2000$ gauss, have been found to be

$$m = 4.74 \frac{\text{meter}^2 \text{ ohm}}{\text{weber}}$$

and

$$K = 1.9 \text{ per ampere,}$$

respectively. Theoretically the oscillator should operate at a control current of about $1/K = 525$ ma; yet, with such magintude of current the specimen is rapidly heated up by the high ohmic loss which causes the internal resistance itself to drop considerably. The condition for oscillation cannot be fulfilled.

According to the reasoning given above, the semiconductor specimen was sawed into 6 small pieces, each of them approximately 1.2 mm long. They were joined together again with indium. The initial resistance of the specimen was found to be somewhat less than before

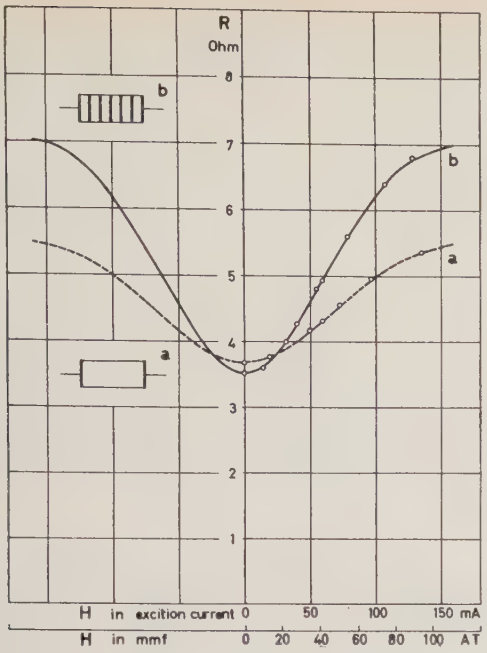


Fig. 6—The magnetoresistance characteristic of a rectangular InSB specimen. Curve *a* is obtained before the specimen is separated into 6 small pieces and curve *b* is obtained after the small pieces are soldered together again.

because of the loss of some material by sawing, but the magnetoresistance characteristic is much improved, as indicated in Fig. 6, curve *B*. With a value of

$$m = 10.05 \frac{\text{meter}^2\ \text{ohm}}{\text{weber}}$$

and a feedback factor $K = 3.75$ per ampere at the same quiescent point, the oscillator should work at a control current of $I = 1/K = 266$ ma. In reality, the oscillator starts to operate stably with a minimum control current of 240 ma, using a condenser of 32 μf for a frequency of 70 cps, at a room temperature of 25°C.

The curve in Fig. 7 shows the relationship between the dc control current and the dc voltage drop in the semiconductor specimen with the current in the field winding being kept constant at 60 ma, equivalent to a bias field of $H = 41.7$ ampere-turns and $B = 2000$ gauss at a room temperature of 25°C. The curve is not a straight line as might be expected. If an effective heat-sink is provided for the specimen, for instance, a good thermo-conductive contact between the specimen and the ferrite core, the curve will be more nearly linear.

As has been discussed previously, the amplitude of the open-circuit output voltage of the oscillator is a function of the control current and the bias field. At suitable bias fields the amplitude of the output voltage in relation to the control current is nonlinear. The voltage grows slowly at first, then increases rapidly and becomes saturated at large control currents as illustrated in Fig. 8. If the control current is too large, the output

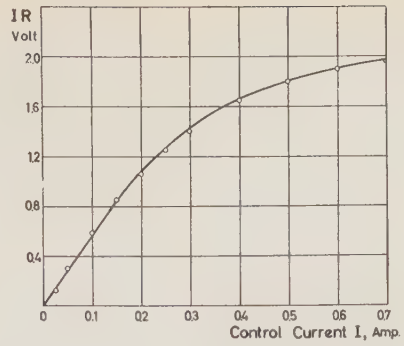


Fig. 7—The dc voltage drop IR across the specimen's terminals in relation to the control current I. The nonlinearity of the curve is caused by the warm-up of the specimen.

voltage has a wave form different from the sine wave, with the crests flattened or bent inward because of the concave shape of the magnetoresistance characteristics at very low flux density and the saturation of the magnetic core at high flux density. (See Fig. 9.)

Keeping the control current constant, the variation of the amplitude of the ac output voltage corresponding to the quiescent point of the field is described by the curves of Fig. 10. Curve 1 is the dc potential drop of the semiconductor specimen against the field intensity, in ampere-turn, and the field current, in ma, representing the magnetoresistance characteristics of the specimen in this particular magnetic core. Curve 2 is representing the peak-to-peak value of the ac voltage at different bias fields, which has a maximum value at the quiescent point A where the slope of curve 1 is a maximum and decreases with the decrease of the slope along the curve beyond this point. If the bias field is too far away from the point A, the output waveform may become asymmetrical or, at worst, the oscillation vanishes.

The growth of the oscillation depends on the initial condition of the condenser and the parameter α. If the initial charge Q on the condenser is zero, the surge current i will jump almost instantaneously from zero to an initial value of $IR_H/\omega L$, after the switch is closed. The equivalent resistance r' for the iron and miscellaneous losses, which is a function of the ac voltage only, increases rapidly from zero to an initial value of r_0'. There are three cases for which the oscillation will be built up under the condition $KI > 1$.

Case 1) when $KI(R_H + r) < (R_H + r + r_0')$, parameter α of (15) becomes positive at the beginning. The oscillation starts with an initial amplitude and then decreases exponentially to a final amplitude, when the resistance r' has been accordingly reduced to such a value that $KI(R_H + r) = R_H + r + r'$. The oscillation is then stable.

Case 2) when $KI(R_H + r) = (R_H + r + r_0')$, α is equal to zero. The oscillation starts with the initial amplitude and remains unchanged.

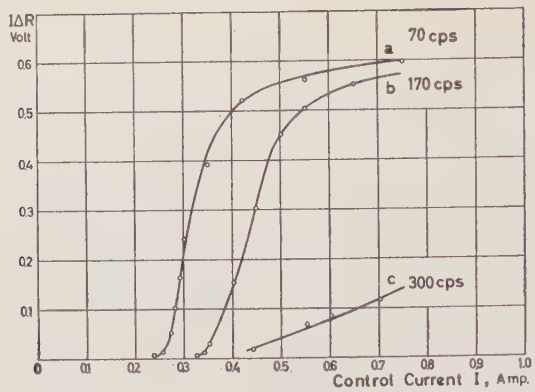


Fig. 8—The peak-to-peak ac voltage across the semiconductor specimen in relation to the control current, at a bias field of 2000 gauss, and its dependence on the frequency of the oscillation, at room temperature of 25°C.

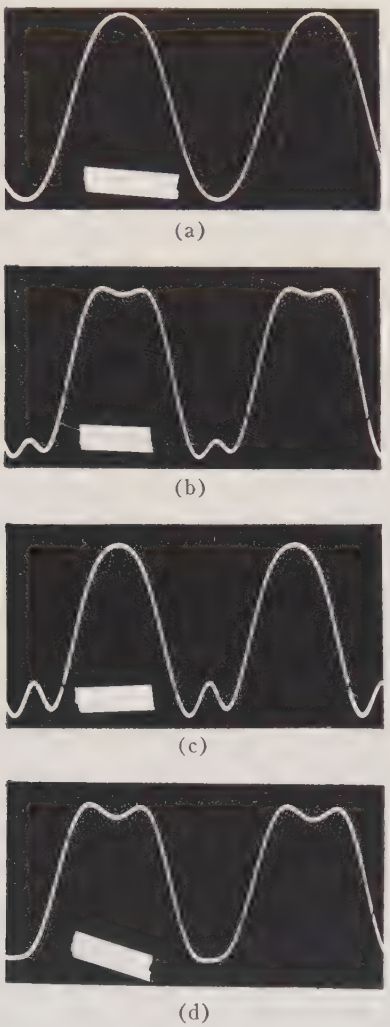


Fig. 9—The waveform of the ac voltage across the semiconductor specimen in relation to the control current and the bias field at a frequency of 70 cps. (a) With bias field = 2000 gauss and control current $I = 650$ ma. The bias field is at the optimum point and the control current is appropriate. The waveform is quite sinusoidal. (b) With bias field = 2000 gauss and control current $I = 760$ ma. The control current is too large for this bias field. (c) With bias field = 1500 gauss and control current $I = 760$ ma. The bias field is too low for this control current. (d) With bias field = 2500 gauss and control current $I = 800$ ma. The bias field is not at the optimum point, being too high, and the control current is inappropriate, being too large.

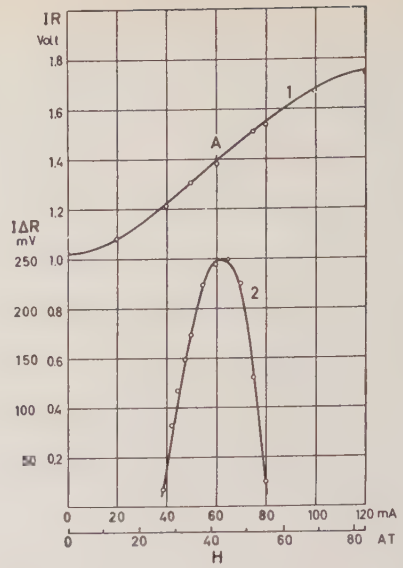


Fig. 10—The peak-to-peak ac voltage across the semiconductor specimen in relation to the bias field with a control current of 300 ma and a frequency of 70 cps, at room temperature of 25°C.

Case 3) when $KI(R_H+r) > (R_H+r+r_0')$, α becomes negative. The oscillation grows from the initial amplitude to a larger value, until the resistance r' reaches a balanced value.

In Fig. 11, (a), (b) and (c), these three cases are illustrated in which the ac voltage difference across the specimen is observed.

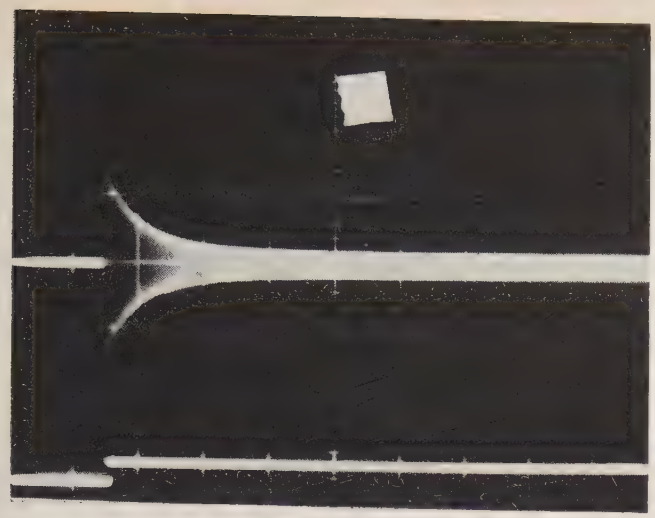
If the initial charge Q on the condenser is almost equal to CIR_H, there will be zero or very little surge current in the circuit shortly after the closing of the switch. The initial value of equivalent loss resistance r' is negligible. The parameter α is then always negative at the beginning, and the oscillation will grow from zero or a very small amplitude to its final value as shown in Fig. 12.

The maximum available output power from this magnetoresistance oscillator is about 2.5 mw. It is obtained by connecting a load resistance of 4 ohm in series with a condenser of 400 μf across the terminals of the specimen. The condenser serves to block the direct current. At a frequency of 70 cps and with a control current $I = 500$ ma the effective voltage across the load resistance is 100 mv which is equivalent to an output power of 2.5 mw.

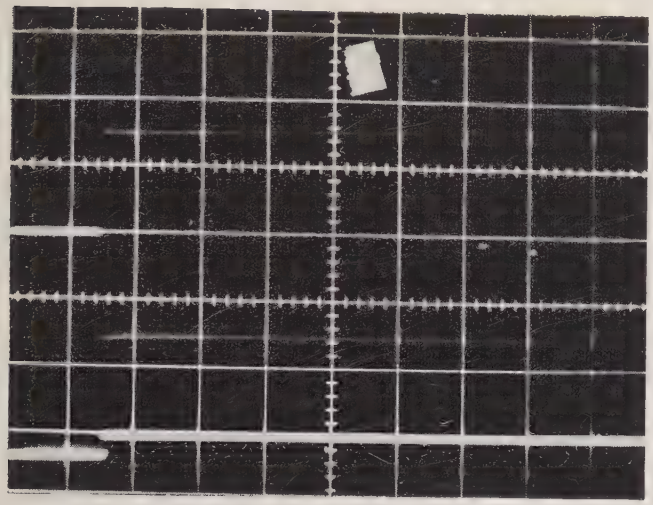
The highest frequency obtainable from the experimental oscillator is about 300 cps. Although the frequency can be adjusted by varying the capacitance C, the upper limit is determined by the output power of the magnetoresistance element and the inductance of the field winding.

Discussion of the Experimental Results

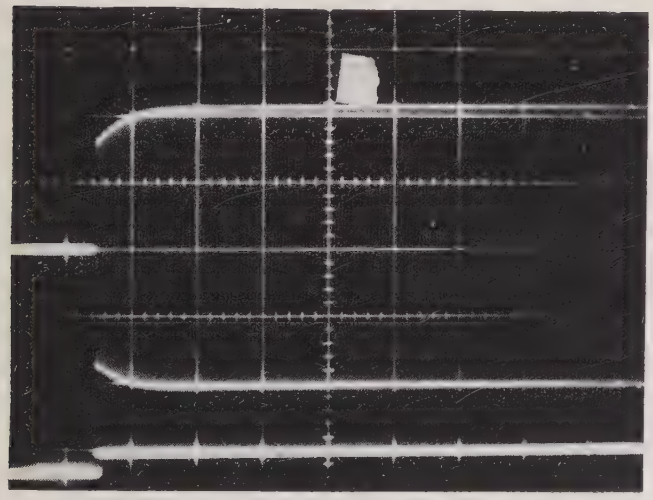
In comparison with a Hall effect oscillator with specimen of similar material and of the same order of magnitude in thickness and volume, the maximum output voltage and power of the present experimental oscillators is smaller. This is partly due to the fact that the



(a)

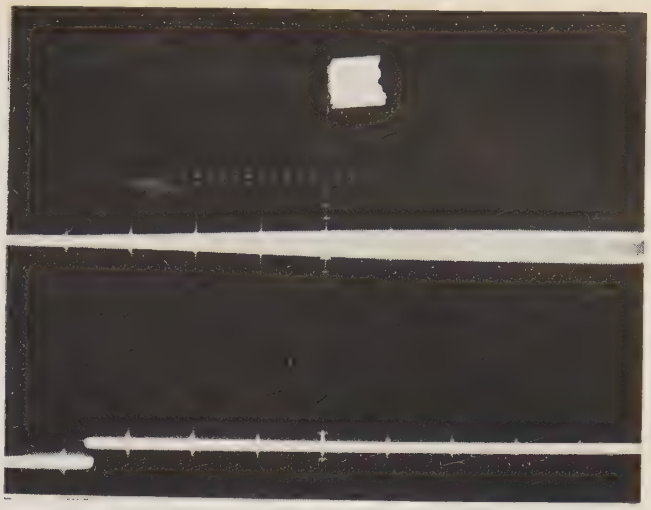


(b)

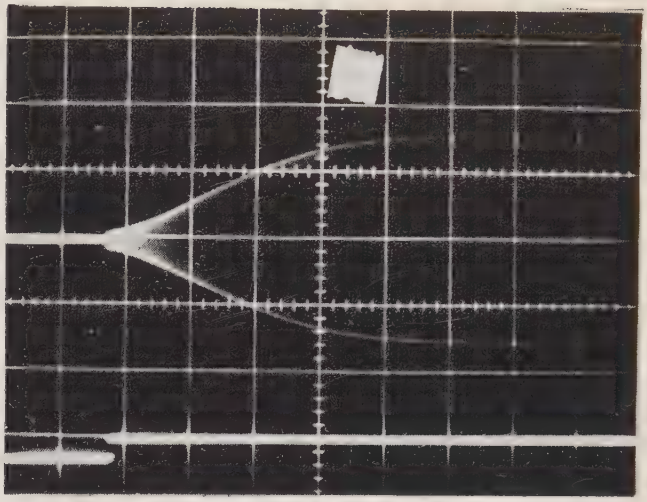


(c)

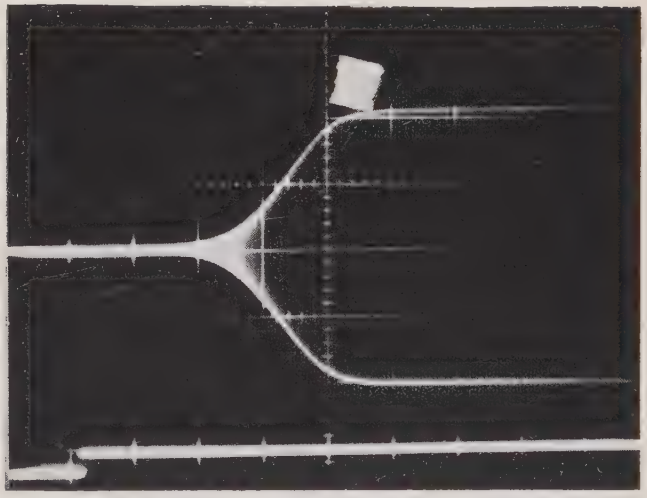
Fig. 11—The growth of the oscillation with initial charge Q on the condenser being zero. The vertical scale indicates the amplitude of the oscillation and the horizontal scale indicates the elapse of time. The step on the straight line at the lower part of the photograph shows the moment $t=0$, when the switch is closed. (a) Case 1. With bias field = 2000 gauss and control current = 280 ma, $KI(R_H+r)<(R_H+r+r_0')$, $\alpha>0$. (b) Case 2, With bias field = 2000 gauss and control current = 320 ma, $KI(R_H+r)=(R_H+r+r_0')$, $\alpha=0$. (c) Case 3. With bias field = 2000 gauss and control current = 420 ma, $KI(R_H+r)>(R_H+r+r_0')$, $\alpha<0$.



(a)



(b)



(c)

Fig. 12—The growth of the oscillation with initial charge $Q=CIR_H$. The parameter α is always negative and the oscillation grows from a zero or very small amplitude to its final value. (a) With bias field = 2000 gauss and control current = 280 ma, corresponding to Fig. 11 (a). (b) With bias field = 2000 gauss and control current = 320 ma, corresponding to Fig. 11 (b). (c) With bias field = 2000 Gauss and control current = 420 ma, corresponding to Fig. 11 (c).

magnetoresistance effect can only make use of approximately half of the complete *B-H* curve of the magnetic core. The low saturation of the ferrite core, about 4000 gauss, as well as the nonsensitive characteristic of the magnetoresistance unit at low induction, less than 1000 gauss, sets further limitations for the output voltage to grow. If ferromagnetic material of higher saturation is used for the core, so that the bias field can be set to a higher induction, the ac power and voltage can be increased.

As the ac voltage and the output power are functions of the control current, they may easily be regulated by varying the control current. If a well-designed heat-sink is provided for the specimen to keep its temperature within acceptable limits, a control current of considerably larger magnitude can be used for the oscillator. It is advisable to use those semiconductors of high mobility but very low temperature coefficient within the ordinary working temperature range, *e.g.*, between zero and 40°C, such as indium arsenide or indium antimonide with impurities properly controlled.

To obtain output frequency in the audio- or radio-frequency range, the inductance of the field winding of the experimental oscillator should be reduced and the power feedback to the field should be increased. This can be done by reducing the length of air gap, increasing the magnitude of the parameter m and by using magnetic core having very low losses, large permeability and high saturation flux density.

The use of choke coils in the input circuit and especially in the bias field circuit is important and necessary as they minimize the miscellaneous losses in the oscillator due to the circulation of the alternating current in these two loops. If a permanent magnet is employed to provide the bias field, the problem of losses is much simpler. To have maximum available power from the oscillator, attention should be paid to the way of connecting the load to the magnetoresistance element. A resistance of low value should not be connected directly to the terminals of the specimen without a condenser in series, otherwise the dc voltage dropped across the specimen will be so seriously reduced that the oscillation stops.

In consideration of the improvement of the magnetoresistance characteristic by means of modification of the geometric form of the specimen, the method that has been described for the experimental oscillator is primitive but reliable. The difficulty is not to cut the thin piece of semiconductor into parts but to solder them together again. Welker[6] has suggested a kind of semiconductor specimen which is long and thin and plated with conducting material, *e.g.*, silver, at intervals along the length of the specimen. This kind of semiconductor specimen, having a thickness in the order of 0.01 to 0.02 mm and an initial resistance of 10 to 100 ohms, would be suitable for the oscillator because it permits the use of a very small air gap which reduces the power supplied to the field circuit and facilitates the construction of the field coil which should have a resistance almost matched to that of the specimen. Attention should, however, be paid to the thickness of the specimen. If it is too thick in relation with the dimensions of the conducting strips, there may be a leakage path of the carriers underneath the conducting strip introducing additional loss resistance across the semiconductor terminals that may be sufficiently large to upset the condition for oscillation.

As an alternative suggestion of preparing the active element, the pure and highly conductive layer inserted in between the semiconducting layers may be formed during the process of growing the single crystal by using the similar technique employed to control the resistivity and the conductivity in germanium. In principle one should be able to produce a single crystal in which there are pure conductive layers sandwiched between the semiconducting layers with the junctions parallel to each other. The probe prepared from this kind of crystal can be made as thin as the technique permits and the problem of the leakage path can be eliminated.

Conclusion

The application of magnetoresistance effect to oscillators has been demonstrated experimentally. It has been shown that oscillators using high-mobility semiconducting material InSb as the active element can at least operate at much higher temperature than oscillators made of bismuth, and that an oscillator with a properly designed probe can operate satisfactorily and stably at ordinary room temperature. The elimination of the equipment to provide the low temperature, *i.e.*, below 0°C for the oscillator, has proved that magnetoresistance effect can be made good use of for electronic devices without requiring a complicated circuit arrangement.

Through proper choice and design of the active element and the magnetic core, the performance of the given experimental oscillator can be much improved. By use of a magnetic core of higher saturation flux density and higher permeability than those of ferrites, with an air gap of much smaller length to accommodate a specimen of high initial resistance but in similar order of magnitude of magnetoresistance effect as a Corbino disk, it should not be difficult to have an oscillator of considerable output power operating with a frequency in the audio- and radio-frequency range at room temperature. If the temperature coefficient of the active element within the ordinary operating temperature range is made to be very small and a good heat-sink is provided, control current of considerably larger magnitude can be applied to the oscillator to produce large output ac power.

The magnetoresistance effect oscillator can be built

[6] H. Welker, "Neue Werkstoffe mit grossem Hall-Effekt und grosser Widerstandsänderung im Magnetfeld," *Elekt. Tech. Z.* (*A*), vol. 76, pp. 513–517; August, 1955.

in a compact and shock-proof form. It requires no heat-up time and the oscillation can be started instantaneously under given initial conditions.

In principle any electronic device based upon Hall effect can be replaced by a similar device based upon magnetoresistance effect. Theoretically, magnetoresistance effect devices should have much higher efficiency and sensitivity than those of the Hall effect devices, when the operating magnetic field is well over 3000 gauss. In another method of making use of the magnetoresistance effect, oscillators as well as other kinds of devices can be constructed with two magnetoresistance elements connected in a push-pull circuit. This will greatly improve the performance of the device. Some of these experiments have been carried out and the results are to be published elsewhere.

Acknowledgment

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A Simplified Stability Criterion for Linear Discrete Systems*

E. I. JURY†, SENIOR MEMBER, IRE

Summary—**In this study a simplified analytic test of stability of linear discrete systems is obtained. This test also yields the necessary and sufficient conditions for a real polynomial in the variable z to have all its roots inside the unit circle in the z plane. The new stability constraints require the evaluation of only half the number of Schur-Cohn determinants [1], [2]. It is shown that for the test of a fourth-order system only a third-order determinant is required and for the fifth-order, one second-order and one fourth-order determinant are required. The test is applied directly in the z plane and yields the minimum number of constraint terms. Stability constraints up to the sixth-order case are obtained and for the nth-order case are formulated. The simplicity of this criterion is similar to that of the Liénard-Chipard criterion [3] for the continuous case which has a decisive advantage over the Routh-Hurwitz criterion [4], [5]. Finally, general conditions on the number of roots inside the unit circle for n even and odd are also presented in this paper.**

I. Introduction

IT IS KNOWN THAT linear time-invariant discrete systems can be described by constant coefficient linear difference equations. These equations can be easily transformed into the function of the complex variable z by the z-transform method. One of the problems in the analysis of such systems is the test for stability, *i.e.*, to determine the necessary and sufficient conditions for the roots of the system characteristic equation to lie inside the unit circle in the z plane. These stability tests involve both graphical procedures such as Nyquist locus, Bode diagrams, and the root-locus, and analytical methods such as Schur-Cohn or Routh-Hurwitz criteria. Because of the higher order determinants to be evaluated using the presented form of the Schur-Cohn criterion, many authors in the past have used either a unit shifting transformation [6][1] or bilinear transformation [7]. The latter transformation maps the inside of the unit circle in the $z=e^{Ts}$ plane into the left half of the w plane[2] and then applies the Routh-Hurwitz criterion. This transformation involves two difficulties: 1) algebraic manipulation for higher-order systems becomes complicated, and 2) the final constraints on the coefficients in the z plane become unwieldy and require algebraic reductions to yield the minimum number of terms. Because of these limitations this criterion is not usually used for systems higher than second-order.

A recent investigation by this author has shown that the evaluation of the Schur-Cohn determinants can be simplified considerably by making use of the real coefficients of the polynomial in z, so that the manipulation involved in testing for the zeros of a polynomial are comparable to those using the "transformed (or modified) Routh-Hurwitz criterion," thus avoiding the bilinear transformation [8], [9].

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[1] This transformation uses $p=z-1$.

[2] This transformation uses

$$z=\frac{w+1}{w-1}.$$

The study in this paper represents a major simplification of the earlier work [8], [9] where it is shown that only half the number of determinants are required for obtaining the stability constraints. This simplification has a decisive advantage over the modified Routh-Hurwitz criterion and, indeed, higher-order systems can easily be tackled using the proposed stability test.

II. Theoretical Background

In this section we review the simplifications which had been obtained in an earlier publication [8], [9] and explain in detail the manipulations involved.

Schur-Cohn criterion [1], [2]:

If for the polynomials

$$F(z) = a_0 + a_1 z + a_2 z^2 + \cdots + a_n z^n \tag{1}$$

all the determinants of the matrices

$$\Delta_k = \begin{bmatrix} a_0 & 0 & 0 & 0 & \cdots 0 & a_n & a_{n-1} & \cdots a_{n-k+1} \\ a_1 & a_0 & 0 & 0 & \cdots 0 & 0 & a_n & \cdots a_{n-k+1} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ a_{k-1} & a_{k-2} & & a_{k-3} & \cdots a_0 & 0 & 0 & \cdots a_n \\ \bar{a}_n & 0 & & 0 & \cdots 0 & \bar{a}_0 & \bar{a}_1 & \cdots \bar{a}_{k-1} \\ \bar{a}_{n-1} & \bar{a}_n & & 0 & \cdots & \cdot & \cdot & \cdots \\ \cdot & \cdot & & \cdot & & \cdot & \cdot & \cdot \\ \cdot & \cdot & & \cdot & & \cdot & \cdot & \cdot \\ \cdot & \cdot & & \cdot & & \cdot & \cdot & \cdot \\ \bar{a}_{n-k+1} & \bar{a}_{n-k+2} & & \bar{a}_{n-k+3} & \cdots \bar{a}_n & 0 & 0 & \cdots \bar{a}_0 \end{bmatrix} \tag{2}$$

$k = 1, 2, 3, \cdots n$, $\bar{a}_k$ = complex conjugate of a_k are different from zero, then $F(z)$ has no zeros on the circle $|z| = 1$ and μ zeros in this circle, μ being the number of variations in sign in the sequence 1, $|\Delta_1|$, $|\Delta_2|$, $\cdots$, $|\Delta_n|$. The proof of the above theorem is quite involved and is available in the literature [1], [2]. This criterion was first introduced by Cohn in 1922, and since that time neither engineers nor mathematicians have simplified it to a usable form.

For a system of order n to be stable, all the n zeros of its characteristic nth order equation must lie within the unit circle, *i.e.*, the sequences 1, $|\Delta_1|$, $|\Delta_2|$, $\cdots$, $|\Delta_n|$ must have n variations in sign. The stability criterion can, therefore, be expressed by the constraints [4]:

$$\left.\begin{array}{l} |\Delta_k| < 0, \ k \text{ odd} \\ |\Delta_k| > 0, \ k \text{ even} \end{array}\right\} \quad k = 1, 2, \cdots, n. \tag{3}$$

For a discrete or a sampled-data system, all the coefficients of the characteristic equation are real. Hence, the conjugate sign in (2) is superfluous. It is the utilization of this fact that leads to the simplification of (2).

As noticed from (2), the highest-order determinant $|\Delta_n|$ is of order $2n$, while the characteristic equation is of order n. Hitherto this contituted one of the discouraging facts in widely using the criterion for higher-order sampled-data systems. A recourse to transformation to other planes was therefore attempted to yield easier stability tests.

III. Simplification of the Stability Constraint Equation [8], [10]

Since all a_k in (2) are real, the matrix can be written as

$$\Delta_k = \begin{bmatrix} P_k & Q_k \\ Q_k^T & P_k^T \end{bmatrix} \tag{4}$$

where the superscript T denotes transpose and

$$P_k = \begin{bmatrix} a_0 & 0 & 0 & \cdots 0 \\ a_1 & a_0 & 0 & \cdots 0 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ a_{k-1} & a_{k-2} & a_{k-3} & \cdots a_0 \end{bmatrix}, \tag{5}$$

$$Q_k = \begin{bmatrix} a_n & a_{n-1} & \cdots & a_{n-k+1} \\ 0 & a_n & \cdots & a_{n-k+2} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 0 & 0 & \cdots & a_n \end{bmatrix}. \tag{6}$$

It is noticed that all the diagonal terms of each of P_k and Q_k are equal; each is symmetric with its cross diagonal. It is this characteristic of the Schur-Cohn matrix that leads to the following simplification [1], using a unitary transformation.

$$|\Delta_k| = |X_k + Y_k| \, |X_k - Y_k|, \tag{7}$$

where X_k and Y_k are given as follows:

$$X_k = \begin{bmatrix} a_0 & a_1 & a_2 \cdots a_{k-1} \\ 0 & a_0 & a_1 \cdots a_{k-2} \\ \cdot & & \\ \cdot & 0 & 0 \cdots a_1 \\ \cdot & & \\ 0 & 0 & 0 \cdots a_0 \end{bmatrix} \tag{8}$$

and

$$Y_k = \begin{bmatrix} a_{n-k+1} \cdots a_{n-1} & a_n \\ a_{n-k+2} \cdots a_n & 0 \\ \cdot & \\ \cdot & \\ \cdot & \\ a_{n-1} \quad \cdots 0 & 0 \\ a_n \quad \cdots 0 & 0 \end{bmatrix}. \tag{9}$$

Thus the Schur-Cohn determinant $|\Delta_k|$ is reduced to the product of two k-order determinants [1], [2] which is considerably easier to evaluate than the $2k$-order determinant $|\Delta_k|$. If a_k is complex, then this simplification is no longer possible [1], [2].

IV. The Symmetrical Properties of $|X_k+Y_k|$ $|X_k-Y_k|$ [8]

Now $|X_k+Y_k|$ is a homogeneous polynomial of dimension k in the variables $a_0, \cdots, a_n$. The polynomial $|X_k-Y_k|$ is identical to the polynomial $|X_k+Y_k|$ except for a change of sign of those monomial terms which have an odd number of elements from Y_k, *i.e.*,

$$|X_k + Y_k| = A_k + B_k \tag{10}$$[3]

$$|X_k - Y_k| = A_k - B_k \tag{11}$$

where $A_k(B_k)$ is the sum of all monomial terms which do not change (do change) sign when Y_k is replaced by $-Y_k$ in $|X_k+Y_k|$.

V. Identification of A_k and B_k

(which we designate as the stability constants) [8].

1) Let all the a_i's in the matrix Y_k in (9) be denoted by b_i's; then expand the determinant $|X_k+Y_k|$ in terms of a_i and b_i.
2) After expansion, examine every term which is a product of a_i's and b_i's; if it contains an even number (including zero) of b_i's, then it is assigned to A_k; otherwise assign the term to B_k.
3) After collecting the terms of A_k and B_k, replace all the b_i's by the a_i's. Hence,

$$|\Delta_k| = (A_k + B_k)(A_k - B_k) = A_k^2 - B_k^2 \tag{12}$$[3]

and for stability from (3) this reduces to

$$\left.\begin{aligned} |A_k| &> |B_k|, \ k \text{ even} \\ |A_k| &< |B_k|, \ k \text{ odd} \end{aligned}\right\} \quad k = 1, 2, \cdots, n. \tag{13}$$

Therefore, the application of the Schur-Cohn criterion now reduces to the evaluation of determinants up to order n only for the nth order polynomial.

It should be noted that the last simplification is useful only for design procedures where the coefficients of $F(z)$ are given in other than numerical values. However, if a_k's are given in numerical values, the use of (10) and (11) is preferred for computer calculations.

[3] From (8) and (9), by replacing all the a's of Y_k by b's, we obtain A_k and B_k by first expanding the following determinant:

$$|X_k + Y_k| = \begin{vmatrix} a_0+b_{n-k+1} & a_1+b_{n-k+2} & a_2+b_{n-k+3} \cdots & a_{k-2}+b_{n-1} & a_{k-1}+b_n \\ b_{n-k+2} & a_0+b_{n-k+3} & a_1+b_{n-k+4} \cdots & a_{k-3}+b_n & a_{k-2} \\ b_{n-k+3} & b_{n-k+4} & a_0+b_{n-k+5} \cdots & a_{k-4} & a_{k-3} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ b_{n-2} & b_{n-1} & b_n \ 0 \ 0 \cdots & a_1 & a_2 \\ b_{n-1} & b_n & 0 \ 0 \ 0 & a_0 & a_1 \\ b_n & 0 & 0 \ 0 \ 0 & 0 & a_0 \end{vmatrix} \tag{13a}$$

$$k = 1, 2, \cdots, n-1, n$$

VI. Equivalence of the Last Constraint $|A_n| \gtrless |B_n|$ to a Simple Auxiliary Constraint [9]

This equivalence constitutes the second major simplification of the original Schur-Cohn criterion. It reduces the stability test considerably. In this equivalence it has been shown that when the first $(n-1)$ constraints of the A's and B's are satisfied, then for $a_n>0$, the following auxiliary constraints

$$F(1) > 0, \ F(-1) \begin{matrix} > 0, \ n \text{ even} \\ < 0, \ n \text{ odd} \end{matrix} \tag{14}$$

are equivalent to $|A_n| \gtrless |B_n|$, depending on n. For any a_n the auxiliary constraint can be written as

$$F(1) \cdot F(-1) \begin{matrix} > 0, \ n \text{ even} \\ < 0, \ n \text{ odd} \end{matrix}.$$

In the Section VII the exact mathematical relationship between $A_n^2-B_n^2$ and the auxiliary constraint will be introduced.

VII. Reduction in the Number of Determinants for Obtaining the Stability Constants A_k's and B_k's

In this section we will show that for the stability test only about half the number of determinants for obtaining the A_k's and B_k's are required. This important reduction is based on certain properties that exist between the A_k's and B_k's. We will indicate these properties first and then show how they can be used for this major simplification.

1) $A_k^2 \gtrless B_k^2 \Leftrightarrow A_{k-1}A_{k+1} \gtrless B_{k-1}B_{k+1}$,

$$k = 2, 3, 4, \cdots, n-1. \tag{15}$$[4]

[4] The above first property is also equivalent to

$$A_k^2 - B_k^2 = A_{k-1}A_{k+1} - B_{k-1}B_{k+1}, \quad k = 2, 3, 4, \cdots, n-1. \tag{15a}$$

The above equivalence is established by expansion for the first few values of $k=2, 3, 4, 5$ and can be generalized similarly for any other values of k.[5] When $k=n-1$, the above equivalence is reduced to

$$A_{n-1}^2 \gtrless B_{n-1}^2 \Leftrightarrow A_{n-2}A_n \gtrless B_{n-2}B_n. \tag{16}$$

This limiting case has been rigorously proven by determinant manipulations using properties 2) and 3). Eq. (15) is the key identity for reducing the determinant of A_k and B_k, for it is noticed that by forcing certain restrictions on the A's and B's before and after a certain k we can dispense with $A_k^2 \gtrless B_k^2$. This will be best illustrated by the few examples to be discussed.

2) $$A_n = (a_0 + a_2 + a_4 + \cdots)(A_{n-1} - B_{n-1}). \tag{17}$$

$$B_n = (a_1 + a_3 + a_5 + \cdots)(A_{n-1} - B_{n-1}), \quad n \geq 2. \tag{18}$$

The above identity can be easily verified for the first few values of n and can be generalized for any n.[6] The importance of this property lies in the mathematical proof of the previous section as follows:

$$A_n^2 \gtrless B_n^2 \Leftrightarrow (a_0 + a_2 + a_4 + \cdots)^2 \gtrless (a_1 + a_3 + a_5 \cdots)^2 \tag{19}$$

or

$$A_n^2 - B_n^2 \gtrless 0 \Leftrightarrow F(1)\cdot F(-1) \gtrless 0 \tag{20}$$

which verifies the equivalence $|A_n| \gtrless |B_n|$ to the auxiliary constraint.

3) $$(A_{n-1} + B_{n-1}) = A_{n-2}(a_0 + a_2 + a_4 + \cdots) - B_{n-2}(a_1 + a_3 + a_5 + \cdots), \quad n \geq 3. \tag{21}$$

The above relationship can also be written as

$$A_{n-1} + B_{n-1} = \tfrac{1}{2}[F(1)(A_{n-2} - B_{n-2}) + F(-1)(A_{n-2} + B_{n-2})]. \tag{22}$$

Eq. (22) has been verified for any $n \geq 3$ by using certain determinant manipulations [11]. The use of the third property lies in the fact that one can obtain $A_{n-1}+B_{n-1}$ from A_{n-2} and B_{n-2}, and most important, to verify the first property for the limiting case, *i.e.*, $k=n-1$, as follows.

The third and second properties can be rewritten as follows:

$$A_{n-1} + B_{n-1} = (a_0 + a_2 + a_4 + \cdots)A_{n-2} - (a_1 + a_3 + a_5 + \cdots)B_{n-2} \tag{23}$$

$$\frac{A_n}{A_{n-1} - B_{n-1}} = (a_0 + a_2 + a_4 + \cdots) \tag{24}$$

$$\frac{B_n}{A_{n-1} - B_{n-1}} = (a_1 + a_3 + a_5 + \cdots). \tag{25}$$

If we multiply (23) by $A_{n-1}-B_{n-1}$ and use (24) and (25), we readily obtain the limiting case of (15a):

$$A_{n-1}^2 - B_{n-1}^2 = A_nB_{n-2} - B_nB_{n-2}. \tag{26}$$

The above three properties in combination with the preceding discussion will now be used in obtaining the new stability constraints for low order systems and then, by generalization, to obtain the constraint for an n-order system.

Examples of Low Order Systems: We will apply the reduction properties wherever they are applicable to $n=3, 4, 5, 6$, and then obtain the stability constraint for any n. We will assume $a_n>0$. This can be easily done by multiplying $F(z)$ by minus one, if necessary.

a) $$n = 3, \quad F(z) = a_0 + a_1z + a_2z^2 + a_3z^3, \quad a_3 > 0. \tag{27}$$

The stability constraints from the modified stability equations (11) and (12) are given by the following inequalities:

$$|a_0| < |a_3|, \quad |A_1| < |B_1| \tag{28}$$

$$|a_0^2 - a_3^2| > |a_0a_2 - a_1a_3|, \quad |A_2| > |B_2| \tag{29}$$[7]

$$F(z)|_{z=1} > 0, \quad F(z)|_{z=-1} < 0, \text{ or } |A_3| < |B_3|. \tag{30}$$

Reduction of the Constraint Conditions: From the first property of the A_k and B_k, we may write in this case

$$A_2^2 > B_2^2 \Leftrightarrow A_1A_3 > B_1B_3. \tag{31}$$

Since B_1 is positive (*i.e.*, $a_3>0$), we may write for the right side

$$\frac{A_1}{B_1}A_3 > B_3. \tag{29a}$$

[5] For values of k up to 15, and for certain n, this equivalence has also been checked numerically. Although a rigorous proof (other than determinant expansion) for (15) has been obtained, by using a heuristic argument however, it can easily be shown [11] that this identity is not violated for all values of k between 5 and $n-1$.

[6] To establish the identity for the general case, [11] it is easier to show the following equivalent conditions for (17) and (18):

$$A_n + B_n = F(1)(A_{n-1} - B_{n-1}); \quad A_n - B_n = F(-1)(A_{n-1} - B_{n-1}).$$

[7] To show how to obtain A_2 and B_2 for this case:
1) Expand the determinant of (13a) for $k=2$ and $n=3$, as follows:

$$|X_2 + Y_2| = \begin{vmatrix} a_0 + b_2 & a_1 + b_3 \\ b_3 & a_0 \end{vmatrix} = a_0^2 + a_0b_2 - a_1b_3 - b_3^2.$$

2) To identify A_2 and B_2, follow procedure 2 in Section V to obtain

$$A_2 = a_0^2 - b_3^2$$
$$B_2 = a_0b_2 - a_1b_3.$$

3) Replace all the b's of A_2 and B_2 by the a's to get

$$A_2 = a_0^2 - a_3^2$$
$$B_2 = a_0a_2 - a_1a_3.$$

A similar procedure is used for obtaining the A_k's and B_k's for any k and n.

Using conditions (28) and (30) in combination with (29a) the new stability constraints are:

$$1) \quad |a_0| < a_3, \text{ or } a_0 - a_3 < 0, \quad a_0 + a_3 > 0, \tag{32}$$

$$2) \quad B_3 < 0, \tag{33}$$

$$3) \quad |A_3| < |B_3|, \text{ or } F(1) > 0, \; F(-1) < 0. \tag{34}$$

From the second property in (18)

$$B_3 = (a_1 + a_3)(A_2 - B_2). \tag{35}$$

Since a_1+a_3 is positive (from (34)) because it is equal to $F(1)-F(-1)>0$, therefore B_3 is negative only when $A_2-B_2<0$. It is of interest to note that from the third property of the stability constants it is readily seen that $A_2+B_2<0$ is identically satisfied from the first and third conditions. Thus the simplified form of the stability constraint for $n=3$ reduces to

$$|a_0| < a_3 \tag{36}$$

$$a_0^2 - a_3^2 < a_0 a_2 - a_1 a_3 \tag{37}$$

$$a_0 + a_1 + a_2 + a_3 > 0, \quad a_0 - a_1 + a_2 - a_3 < 0. \tag{38}$$

b) $n = 4, F(z) = a_0 + a_1 z + a_2 z^2 + a_3 z^3 + a_4 z^4,$

$$a_4 > 0. \tag{39}$$

The stability constraint

$$|a_0| < a_4, \quad |A_1| < |B_1| \tag{40}$$

$$|a_0^2 - a_4^2| > |a_0 a_3 - a_1 a_4|, \quad |A_2| > |B_2| \tag{41}$$

$$|a_0^3 + a_0 a_2 a_4 + a_1 a_3 a_4 - a_0 a_4^2 - a_2 a_4^2 - a_0 a_3^2|$$

$$< |a_0^2 a_4 + a_0^2 a_2 + a_1^2 a_4 - a_0 a_2 a_4 - a_4^3 - a_0 a_1 a_3| \tag{42}$$

or

$$|A_3| < |B_3| \tag{43}$$

$$F(z)|_{z=1} > 0, \quad F(z)_{z=-1} > 0 \text{ or } |A_4| > |B_4|. \tag{44}$$

Reduction of the Constraint Equations: Using property 1), we may write, as in the previous case,

$$A_2^2 > B_2^2 \Leftrightarrow A_1 A_3 > B_1 B_3, \text{ or } \frac{A_1}{B_1} A_3 > B_3. \tag{45}$$

Eqs. (40)–(42) are now equivalent to (40), $B_3<0$ and (42). Using $B_3<0$ with (43), we finally obtain the reduced constraints

$$|a_0| < a_4, \text{ or } |A_1| < B_1 \tag{46}$$

$$A_3 - B_3 > 0, \quad A_3 + B_3 < 0 \tag{47}$[8]$$

$$F(1) > 0, \quad F(-1) > 0. \tag{48}$$

[8] Constraints in (47) can also be written as $B_3<0$, $|A_3|<|B_3|$. The latter has an advantage in numerical testing if $B_3<0$ is violated. Then the test could be discontinued without having to calculate A_3.

It is noticed that for the fourth-order[9] case only one determinant of third-order for obtaining A_3 and B_3 is required. All other conditions are very simple.

c) $n = 5, F(z) = a_0 + a_1 z + a_2 z^2 + a_3 z^3 + a_4 z^4 + a_5 z^5,$

$$a_5 > 0. \tag{49}$$

The stability constraints in symbolic form

$$|A_1| < B_1, \quad B_1 = a_5 > 0 \tag{50}$$

$$|A_2| > |B_2| \tag{51}$$

$$|A_3| < |B_3| \tag{52}$$

$$|A_4| > |B_4| \tag{53}$$

$$F(1) > 0, \quad F(-1) < 0, \text{ or } |A_5| < |B_5|. \tag{54}$$

Reduction of the Constraint Relationship: We may keep in this case condition (51) but we eliminate (52) by using the first property, *i.e.*,

$$A_3^2 < B_3^2 \Leftrightarrow A_2 A_4 < B_2 B_4. \tag{52a}$$

With A_2 negative because of (53),[10] the stability constraint for (50), (52), (52a) and (53) becomes (50), (51), $A_4>0$, and $A_4^2>B_4^2$. Using $A_4>0$ in (56), *i.e.*, $(A_4-B_4)(A_4+B_4)>0$, we obtain $A_4-B_4>0$ and $A_4+B_4>0$. Furthermore, since $A_2=A_1^2-B_1^2$ is to be negative from (50), it is readily satisfied if the second constraint $0+(51)$ is equivalent to $A_2-B_2<0$, $A_2+B_2<0$. Finally, we obtain for the reduced form the following:

$$A_2 - B_2 < 0, \quad A_2 + B_2 < 0 \tag{55}$$

$$A_4 - B_4 > 0, \quad A_4 + B_4 > 0 \tag{56}$$

$$F(1) > 0, \quad F(-1) < 0. \tag{57}$$

It is noticed that in this case only the *second-* and *fourth*-order determinants are required. One may also use a different form of reduction by eliminating (56). However, this will not yield much simplification over the previous form because a fourth-order determinant with a third-order determinant is then required.

[9] An alternate form which is more advantageous for design can be obtained for the fourth-order case. This form can be easily obtained by using properties 1) and 2). It is given as follows:

1) $A_2 < 0$
2) $A_2 < -|B_2|$
3) $A_3 - B_3 > 0$
4) $F(1) > 0, \; F(-1) > 0.$

In this case only one third-order equation in 3) and two second-order equations in 2) are to be solved, while in the former case two third-order equations are to be solved. It should be noted that when 2) is satisfied, relationship 1), *i.e.*, $A_2<0$, becomes redundant. Therefore, the final constraints for $n=4$ can be summarized as [12]:

1) $A_2 < -|B_2|$, or $A_2 - B_2 < 0, \; A_2 + B_2 < 0$
2) $A_3 - B_3 > 0$
3) $F(1) > 0, \; F(-1) > 0.$

[10] Note $A_2=A_1^2-B_1^2$.

d) $n = 6$, $F(z) = a_0 + a_1z + a_2z^2 + a_3z^3 + a_4z^4 + a_5z^5 + a_6z^6$, $a_6 > 0$.

The stability constraints in symbolic form are

$$|A_1| < B_1, \quad B_1 = a_6 > 0 \tag{58}$$
$$|A_2| > |B_2| \tag{59}$$
$$|A_3| < |B_3| \tag{60}$$
$$|A_4| > |B_4| \tag{61}$$
$$|A_5| < |B_5| \tag{62}$$
$$F(1) > 0, \quad F(-1) > 0, \text{ or } |A_6| > |B_6|. \tag{63}$$

Reduction of the Constraint Relationship: In this case we may conveniently eliminate the determinants of (59) and (61) as follows: using first $A_2^2 > B_2^2 \Leftrightarrow A_1A_3 > B_1B_3$, we obtain the equivalent constraint for (58)–(60), noting (45), as follows:

$$|A_1| < B_1, \quad |A_3| < |B_3| \text{ and } B_3 < 0. \tag{64}$$

To eliminate the determinant of (61), we use the following proven identity:

$$A_4^2 > B_4^2 \Leftrightarrow A_3A_5 > B_3B_5. \tag{65}$$

Noting that $B_3 < 0$, and (60) and (62), the above is satisfied if B_5 is positive, and (60) and (62) are also satisfied. Therefore the stability constraints for $n = 6$ now reduce to

$$|A_1| < B_1$$
$$|A_3| < |B_3|, \; B_3 < 0, \text{ or } (A_3 + B_3) < 0, \; (A_3 - B_3) > 0$$
$$|A_5| < |B_5|, \; B_5 > 0, \text{ or } (A_5 + B_5) > 0, \; (A_5 - B_5) < 0$$
$$F(1) > 0, \quad F(-1) > 0. \tag{66}$$

Following the above reduction we can similarly obtain the stability constraints for higher-order systems for the general case, *i.e.*, for any n, by using the first property.

The stability constraints can be presented in either one of the following two forms.

The New Stability Criterion: A necessary and sufficient condition for the polynomial $F(z) = a_0 + a_1z + a_2z^2 + \cdots + a_kz_k + \cdots + a_nz^n$ with $a_n > 0$ to have all its roots inside the unit circle is represented by the following constraints for *n even* and *n odd*, respectively:

n even[11]

$$F(1) > 0, \quad F(-1) > 0$$
$$|A_1| < B_1, \quad B_1 = a_n > 0, \text{ or}$$
$$A_1 - B_1 < 0, \quad A_1 + B_1 > 0$$
$$A_3 - B_3 > 0, \quad A_3 + B_3 < 0$$
$$A_5 - B_5 < 0, \quad A_5 + B_5 > 0$$
$$A_7 - B_7 > 0, \quad A_7 + B_7 < 0$$
$$\vdots \qquad \vdots$$
$$> 0 \quad \text{for } n = 4k$$
$$A_{n-1} - B_{n-1} < 0 \quad \text{for any other } n$$
$$< 0 \quad \text{for } n = 4k$$
$$A_{n-1} + B_{n-1} > 0 \quad \text{for any other } n,$$
$$k = 1, 2, 3 \cdots$$

n odd[11]

$$F(1) > 0, \quad F(-1) < 0$$
$$A_2 - B_2 < 0, \quad A_2 + B_2 < 0$$
$$A_4 - B_4 > 0, \quad A_4 + B_4 > 0$$
$$A_6 - B_6 < 0, \quad A_6 + B_6 < 0$$
$$\vdots \qquad \vdots$$
$$A_{n-1} - B_{n-1} \begin{cases} > 0 & \text{for } n - 1 = 4k \\ < 0 & \text{for any other } (n-1) \\ > 0 & \text{for } n - 1 = 4k \\ < 0 & \text{for any other } (n-1) \end{cases}$$
$$k = 1, 2, 3 \cdots$$

Alternate Form: An alternate equivalent method which is of advantage if the stability constants evaluation is carried out by methods other than a computer is hereby presented.

n even

$$F(1) > 0, \quad F(-1) > 0$$
$$|A_1| < B_1, \quad B_1 = a_n > 0$$
$$|A_3| < |B_3|, \quad B_3 < 0$$
$$|A_5| < |B_5|, \quad B_5 > 0$$
$$|A_7| < |B_7|, \quad B_7 < 0$$
$$\vdots \qquad \vdots$$
$$|A_{n-1}| < |B_{n-1}|, \quad B_{n-1} \begin{cases} < 0, & \text{for } n = 4k \\ > 0, & \text{for any other } n \end{cases}$$
$$k = 1, 2, 3 \cdots$$

n odd

$$F(1) > 0, \quad F(-1) < 0$$
$$|A_2| > |B_2|, \quad A_2 < 0$$
$$|A_4| > |B_4|, \quad A_4 > 0$$
$$|A_6| > |B_6|, \quad A_6 < 0$$
$$\vdots \qquad \vdots$$
$$> 0, \text{ for } n - 1 = 4k$$

[11] Note that $A_k + B_k$ and $A_k - B_k$ can be obtained directly from (10) and (11).

$$|A_{n-1}| > |B_{n-1}|, \quad A_{n-1} < 0, \text{ for any other } n-1$$
$$k = 1, 2, 3 \cdots$$

In the above case the identification of $|A_k|$ and $|B_k|$ from the determinant $|X_k+Y_k|$ could be used. This criterion can be applied for design purposes when the a_k's of $F(z)$ are given other than numerically.

Summary of Stability Constraints for Low-Order Systems: In this section the constraints in terms of the coefficients of the low-order polynomials are presented.

$n = 2$

$$F(z) = a_0 + a_1 z + a_2 z^2, \quad a_2 > 0$$

1) $|a_0| < a_2$, or $a_0 - a_2 < 0$

2) $a_0 + a_1 + a_2 > 0, \quad a_0 - a_1 + a_2 > 0$

$n = 3$

$$F(z) = a_0 + a_1 z + a_2 z^2 + a_3 z^3, \quad a_3 > 0$$

1) $|a_0| < a_3$

2) $a_0^2 - a_3^2 < a_0 a_2 - a_1 a_3$

3) $a_0 + a_1 + a_2 + a_3 > 0, \quad a_0 - a_1 + a_2 - a_3 < 0$

$n = 4$

$$F(z) = a_0 + a_1 z + a_2 z^2 + a_3 z^3 + a_4 z^4, \quad a_4 > 0$$

1) $a_0^2 - a_4^2 - a_0 a_3 + a_1 a_4 < 0$

2) $a_0^2 - a_4^2 + a_0 a_3 - a_1 a_4 < 0$

3) $a_0^3 + 2a_0 a_2 a_4 + a_1 a_3 a_4 - a_0 a_4^2 - a_2 a_4^2 - a_0 a_3^2 - a_0^2 a_4 - a_0^2 a_2 - a_1^2 a_4 + a_4^3 + a_0 a_1 a_3 > 0$

4) $F(1) > 0, \quad F(-1) > 0$

Evaluation of the Stability Determinants [17]: To evaluate the A_k's and B_k's from (13), we need to expand this determinant only for $k=n-1$. All other values of k can be obtained from this expansion by a limiting process as follows:

To obtain $|X_{n-3}+Y_{n-3}|$ from $|X_{n-1}+Y_{n-1}|$, we let (in the latter) $a_0=0$, $a_1=0$ and $a_i \to a_{i-2}$, and then divide by $-1/b_n^2$. Similarly, we can obtain all the other $|X_k+Y_k|$ by a similar limiting process.

For the case when the coefficients of $F(z)$ are given in numbers, one can use (13a) only for $k=n-1$, and only by letting the b_i's as $+a_i$'s obtain for $A_{n-1}+B_{n-1}$, and as $-a_i$'s obtain for $A_{n-1}-B_{n-1}$. This is evident if the determinant is written in detail; one can notice that it includes inside all other determinants for other values of k.

Relationship Between the New Criterion and Hurwitz Determinants: In this paper some relationships between the new stability constraints and the Hurwitz constraints are established. To show this relationship, we use the bilinear transformation $z=(w+1)/(w-1)$ in $F(z)$, (1), with $a_n>0$, to obtain the following Hurwitz polynomial:

$$F_1(w) = b_0 + b_1 w + b_2 w^2 + \cdots + b_n w^n,$$

where b_k is a linear combination of the a_k's in $F(z)$. The following relationships exist:

a) $F(z)|_{z=1} b_n, \qquad F(z)|_{z=-1} = (-1)^n b_0$

b) *n odd*

$$|\Delta_{n-1}^H| = 2^{(n/2)(n-1)}(A_{n-1} - B_{n-1}), \quad \text{for } n = 4k, \ k = 1, 2, 3$$
$$= -2^{(n/2)(n-1)}(A_{n-1} - B_{n-1}), \quad \text{for any other } n,$$

n even

$$|\Delta_{n-1}^H| = 2^{(n/2)(n-1)}(A_{n-1} - B_{n-1}), \quad \text{for } n-1 = 4k, \ k = 1, 2, 3$$
$$= -2^{(n/2)(n-1)}(A_{n-1} - B_{n-1}), \quad \text{for any } y \text{ other } n,$$

where $|\Delta_{n-1}^H|$ is the next to last Hurwitz determinant. The above relationships have been verified by expansion for low-order systems and can be generalized for any order.

It should be noted that if the constraints of the new stability criterion for n even are written in even form (*i.e.*, in terms of A_k and B_k where k is even), then the last constraint could be terminated by

$$A_{n-1} - B_{n-1} \begin{matrix} > 0 \\ < 0 \end{matrix}.$$

This can be easily obtained by using properties 1) and 2). A similar form can be obtained of n odd if its stability constraints are written in terms of odd forms of A_k and B_k. Thus, one can show that next to the last Hurwitz constraint for the transformed polynomial is identical to the last constraint of the new stability criterion. This simplification could be used to advantage in design in order not to solve two higher-order equations. It is applied to $n=4$ as shown above. Furthermore, if the system is initially stable and some of its parameters change so as to approach instability, the constraint $A_{n-1}-B_{n-1}$ is the most critical one. Hence, to obtain the maximum parameter variations for stability limit only the equation of $(A_{n-1}-B_{n-1})$ need be solved.

Number of Roots of a Real Polynomial Inside the Unit Circle: The preceding criterion yields the necessary and sufficient condition for all the roots of $F(z)$ to lie inside the unit circle. To obtain information on the number of roots that lie inside the unit circle if the system is unstable, we can usefully modify the above discussions to cover this case. Following the original work of Schur-Cohn [1], [2] and its modified form [9], and using the first property of the stability constants A_k's and B_k's, one can state the following.

The number of roots of $F(z)$ that lie inside the unit circle is equal to the number of variations of sign of the following constraints:

n even

$$
\begin{array}{c}
1 > 0 \\
|A_1| \gtrless |B_1| \\
|A_2| \gtrless |B_2| \Leftrightarrow A_1A_3 \gtrless B_1B_3 \\
|A_3| \gtrless |B_3| \\
|A_4| \gtrless |B_4| \Leftrightarrow A_3A_5 \gtrless B_3B_5 \\
|A_5| \gtrless |B_5| \\
\vdots \\
|A_{n-1}| \gtrless |B_{n-1}| \\
A_n^2 - B_n^2 \begin{matrix} > 0 \\ < 0 \end{matrix} \Leftrightarrow |A_n| \gtrless |B_n| \Leftrightarrow F(1)F(-1) \begin{matrix} > 0 \\ < 0 \end{matrix},
\end{array}
$$

n odd

$$
\begin{array}{c}
1 > 0 \\
|A_2| \gtrless |B_2| \\
|A_3| \gtrless |B_3| \Leftrightarrow A_2A_4 \gtrless B_2B_4 \\
|A_4| \gtrless |B_4| \\
|A_5| \gtrless |B_5| \Leftrightarrow A_4A_6 \gtrless B_4B_6 \\
|A_6| \gtrless |B_6| \\
\vdots \\
|A_{n-1}| \gtrless |B_{n-1}| \\
A_n^2 - B_n^2 \begin{matrix} > 0 \\ < 0 \end{matrix} \Leftrightarrow |A_n| \gtrless |B_n| \Leftrightarrow F(1)F(-1) \begin{matrix} > 0 \\ < 0 \end{matrix}
\end{array}
$$

It is noticed from the above that for n even one need not have to evaluate the even determinants but can use the relationship $A_k^2 \gtrless B_k^2 \Leftrightarrow A_{k-1}A_{k+1} \gtrless B_{k-1}B_{k+1}$ which are obtained from the calculated odd determinants. Similarly, the odd determinants are to be avoided from n odd. It is assumed that in this counting neither one of the constants A_k is equivalent to B_k. For such a case special procedure should be used and this will be discussed in a somewhat differently related criterion [16].

VIII. Conclusion

From the preceding discussion, it is shown first that in the original Schur-Cohn or the modified Routh-Hurwitz criteria, the number of determinants required for the stability is almost halved. The use of the criteria for both design of discrete systems as well as for testing roots of a polynomial inside the unit circle is evident. This criterion will now be useful in many applications such as the stability test of difference equations with constant and periodically varying coefficients, in non-linear discrete systems for the stability study of limit cycles, in some applications of digital computers, in the stability test of linear systems with randomly-varying parameters, and in many other applications, such as economic and inventory systems. Thus it is hoped that this criterion will find many applications in various fields in addition to the above, and its use by engineers, physicists and mathematicians will be greatly enhanced. The evaluation of the higher order determinants could also be reduced to evaluation of only second order determinants by using alternate but equivalent forms of the criterion. The discussion of these alternate forms has been recently presented [13–15] and in future publications the connection between the various forms of these stability criteria will be discussed [16].

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Linear Decision Functions, with Application to Pattern Recognition*

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Summary—Many pattern recognition machines may be considered to consist of two principal parts, a receptor and a categorizer. The receptor makes certain measurements on the unknown pattern to be recognized; the categorizer determines from these measurements the particular allowable pattern class to which the unknown pattern belongs. This paper is concerned with the study of a particular class of categorizers, the linear decision function. The optimum linear decision function is the best linear approximation to the optimum decision function in the following sense:

1) "Optimum" is taken to mean minimum loss (which includes minimum error systems).
2) "Linear" is taken to mean that each pair of pattern classes is separated by one and only one hyperplane in the measurement space.

This class of categorizers is of practical interest for two reasons:

1) It can be empirically designed without making any assumptions whatsoever about either the distribution of the receptor measurements or the *a priori* probabilities of occurrence of the pattern classes, providing an appropriate pattern source is available.
2) Its implementation is quite simple and inexpensive.

Various properties of linear decision functions are discussed. One such property is that a linear decision function is guaranteed to perform at least as well as a minimum distance categorizer. Procedures are then developed for the estimation (or design) of the optimum linear decision function based upon an appropriate sampling from the pattern classes to be categorized. Finally, the concepts and procedures thus developed are applied for illustrative purposes to the recognition of hand-printed numbers.

Introduction

THIS PAPER[1] is concerned with the practical design of a class of pattern recognition machines which is of interest for two reasons:

1) There is no need to make assumptions about the probability distributions of the various measurements made by the recognition machine.
2) This class of machines is amenable to an economic implementation.

Marill and Green [16] have described the general pattern recognition system in a very clear manner. They note that it consists of two principal parts, a *receptor* and a *categorizer:*

1) "The receptor has as its input a physical sample to be recognized, and as its output a set . . . of quantities which characterize the physical sample. These quantities will be called *measurements* of the sample . . . "
2) "The output . . . of the receptor constitutes the input to the categorizer. The categorizer is a device which assigns each of its . . . inputs to one of a finite number . . . of categories . . . "

The measurements which a receptor makes on the input sample may be either continuous or discrete, and a given receptor may be required to make measurements of both types. For instance, a character recognition machine might have a receptor which makes the following measurements on an unknown character: the number of closures, cusps and straight lines (discrete), and the length and direction of the straight lines (continuous).

The categorizer must apply some sort of decision criterion to the receptor output to decide to which of the allowable pattern classes, if any, the input pattern belongs. Or the categorizer may reject the pattern as being unrecognizable if the recognition decision is unreliable in some sense. If the machine attempts a recognition and is wrong, then it is said that the machine has made an *error*. Note that a rejection will not be considered as an error.

The Decision Theory Model of Pattern Recognition [5], [19]

Let the p allowable pattern classes be denoted s_i, $1 \leq i \leq p$, each having *a priori* probability of occurrence ω_i, where

$$\sum_{i=1}^{p} \omega_i = 1.$$

When an unknown pattern is presented to the receptor, the receptor makes certain measurements, n in number, upon it. The receptor output for a particular input pattern is the set of numbers $(m_1, m_2, \cdots, m_n) = m$. This set defines the coordinates of the point representing the input pattern in an n-dimensional *measurement space* M.

We assume the existence of a probability function (or density) over M, $\beta(M|S)$. Thus $\beta(m|s_i)$ is the conditional probability that a certain measurement m will be made, given a pattern from class i at the receptor.

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[1] Since this paper is a summary of a Doctoral Dissertation [12], some of the topics and theorem proofs are omitted for the sake of brevity. Copies of the complete dissertation are available from University Microfilms, 313 N. First St., Ann Arbor, Mich.

Let there also exist a probability function (or density) $\delta(D|M)$, so that $\delta(d_j|m)$ is the probability that the categorizer will make the decision d_j, $0 \leq j \leq p$, given the measurement m. ($j=0$ corresponds to rejection; $1 \leq j \leq p$ corresponds to classification into one of the p pattern classes.) $\delta(D|M)$ is referred to as the *decision function* or *decision criterion. Note that the categorizer is nothing more than the implementation of the function* $\delta(D|M)$.

Let a loss (or cost) function $C(S, D)$ now be defined such that $C(s_i, d_j) = c_{ij}$ is the loss (cost) associated with making the decision d_j when the actual input state was s_i. The desired decision is d_i when the input state is s_i; therefore, the usual case requires that

$$c_{ij} > c_{i0} > c_{ii},$$

where c_{i0} is the loss associated with rejection when the input state is s_i.

The probability of making a decision d_j when the input state is s_i is

$$p(d_j|s_i) = \int_M \beta(m|s_i)\delta(s_j|m)dm.$$

The loss when s_i is the input state (called the conditional loss) and when the decision function $\delta(D|M)$ is used is then

$$\bar{C}(s_i, \delta) = \sum_{j=0}^{p} c_{ij} \int_M \beta(m|s_i)\delta(d_j|m)dm. \qquad (1)$$

Since the distribution of states is given by ω_i, $1 \leq i \leq p$, the expected loss for the pattern recognition system is

$$C(\delta) = \sum_{i=1}^{p} \sum_{j=0}^{p} c_{ij}\omega_i\beta(m|s_i)\delta(d_j|m)dm. \qquad (2)$$

The optimum categorizer is defined as the implementation of that decision function δ^* which minimizes the expected loss $C(\delta)$ under the appropriate *a priori* distribution ω_i, $1 \leq i \leq p$, (Bayes strategy).

The general solution to this problem has been given by Chow [6]. He shows that (2) is minimized by using a certain nonrandomized decision criterion (*i.e.*, $\delta(D|m)$ is unity for one decision d_j, and zero for all others).

It has also been shown [10] that if all losses due to misrecognition are of value c, all losses due to rejection are of value c_0, and all losses due to correct recognition are zero, where

$$c > c_0 > 0;$$

then minimizing the loss is equivalent to minimizing the error rate for a given rejection rate.

Reference to Chow will show that the optimum decision function depends, aside from the loss function, only upon the quantities

$$\omega_i\beta(m|s_i), \qquad 1 < i \leq p.$$

Unfortunately, these probability functions, particularly $\beta(M|S)$, are usually unknown to the designer, and therefore categorizers based on the optimum decision function are not, in general, practically realizable. There are at least two ways around this difficulty:

1) Assume a certain form for the probability function $\beta(M|S)$. A common assumption is that of normality and independence: Given a certain pattern class, assume that the measurements made by the receptor are normally distributed, and that each measurement is independent of the others.
2) Make no assumptions about the particular distributions involved, but rather make certain restrictions on the structure of the categorizer. Then search through all possible structures of this type to find the categorizer which is optimum with respect to a sampling of patterns from the real world.

Clearly, neither of these approaches will yield a truly optimum categorizer, the first because of questionable assumptions, the second because of structural limitations. However, the use of either approach now makes the problem manageable, and optimum is reinterpreted to mean minimum loss within the framework of the approach.

Linear Decision Functions

There is another practical advantage that is realized by the second approach, namely one of economic feasibility. Even if the optimum decision function were known, its implementation would require, in general, the use of a digital computer or other complex equipment. The cost of such equipment may, in many cases, outweigh the advantages of mechanized categorization. However, if the designer can limit his search to those structures which are economically feasible, and if the optimum structure in this class works well enough for the given purpose, then a technically feasible as well as an economically feasible solution has been found.

This paper is concerned with the study of just such a class of categorizers. To describe this class, consider a rephrasing of the optimum decision criterion. Note that every point in the measurement space M is preassigned to a particular pattern class or to the rejection class by the decision criterion, since it is nonrandomized. Thus, there is a subset M_j of M corresponding to each possible decision d_j, $0 \leq j \leq p$. Further, these subsets are nonoverlapping since the decision function is nonrandomized. The division of M into these subsets then uniquely identifies a certain decision function. We could equally well consider the decision function to be represented by the *boundaries* between the subsets. (Some liberty is taken here, since it will be assumed that a continuous boundary can be passed through a discrete space.) For instance, in Fig. 1 is shown a two-dimensional measurement space (the receptor makes only two measurements

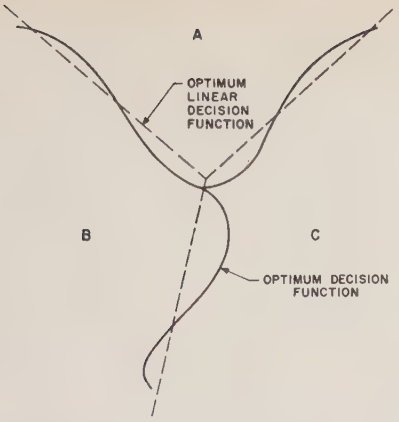

Fig. 1—Domains of three pattern classes in measurement space, as defined by optimum and optimum linear decision functions.

on an input pattern) in which are shown the boundaries (the solid lines) between three different pattern classes, A, B, and C. (For simplicity, rejection regions are not included.) A boundary will, in general, be some sort of curved surface. In fact, the domain of a particular pattern class may not even be singly connected.

The class of categorizers to be discussed herein may be loosely described as the optimum linear approximation to the true boundaries, under the further constraint of only one boundary per pair of pattern classes (such as those shown dotted in Fig. 1). Optimum, as previously mentioned, is taken to mean minimum loss under the above constraints. Because of the linear properties of this decision criterion, a categorizer of this class will be said to implement a *linear decision function*. Although the primary purpose of the development is to study the synthesis of such a categorizer when the probability distributions are unknown, the problem of finding the optimum linear decision function when these distributions are known will also be discussed.

Implementation of a Linear Decision Function

Of particular interest is the economical realization of a categorizer based upon a linear decision function. In an n-dimensional measurement space, a linear decision function will comprise a set of n-dimensional hyperplanes. An n-dimensional hyperplane is represented by that set of all points $(x_1, \cdots, x_n)$ in M which satisfy a linear relation of the form

$$\alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_n x_n + \alpha_0 = 0$$

for a given set of α_i's. The fact that the actual boundaries are only portions of hyperplanes, *i.e.*, each hyperplane usually terminates on other hyperplanes (Fig. 1), is of little consequence. As will be shown in the next section, the representation of each boundary by a full hyperplane is equivalent.

It will be shown later that, in order to classify a point m in M, it is only necessary to determine on which side of each hyperplane this point lies. This is determined by the sign of the quantity[2]

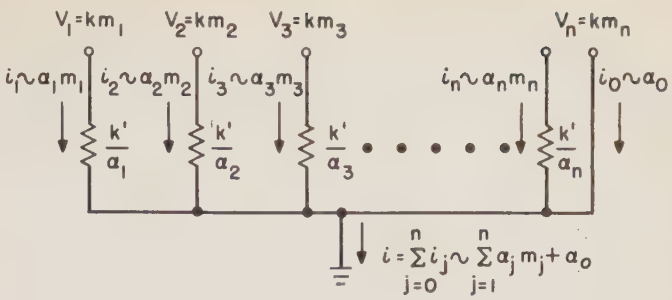

Fig. 2—Implementation of a hyperplane.

$$\sum_{i=1}^{n} \alpha_i m_i + \alpha_0. \tag{3}$$

Consequently, in order to classify a point m (that is, recognize an input pattern), it is only necessary to evaluate a set of quantities like (3). But such a calculation can be done with several varieties of very inexpensive networks, such as the resistive adder shown in Fig. 2 (in which the voltages corresponding to the measurement values are inverted for negative α_i). This supports the statement of economy.

Some Properties of Linear Decision Functions

The Classifying Procedure

Before discussing some of the properties of linear decision functions, the classification procedure will first be discussed. Fig. 3 illustrates a measurement space in which the domains of three pattern classes are shown, as determined by a linear decision function. The boundaries, which are really truncated hyperplanes, will be represented by the complete hyperplanes as indicated by the dotted lines. It will be seen that the truncation is automatically taken into account by the classifying procedure. Since there is one and only one boundary per pair of pattern classes, Fig. 3 shows three boundaries separating the three classes. The boundary separating the ith and jth classes will be denoted B_{ij}. Further, in schematic representation as in Fig. 3, each hyperplane B_{ij} will be identified by the pair of numbers, i, j, placed in such a way as to show which side of B_{ij} corresponds to class i, and which to class j.

In order to classify a certain measurement, we note which side of each boundary it is on. If it is on the ith side of all boundaries B_{ik}, $1 \leq k \leq p$, $k \neq i$, then this pattern belongs to pattern class i. Using this criterion, point A in Fig. 3 is clearly identified as a member of pattern class 2.

Note that the point designated B cannot belong to

[2] Note that this linear form equated to zero defines a structure which is commonly found in the automata field. It goes by various names, such as artificial neuron [14], associative unit [21], [22], and Adaline [26], [27]. In this paper, it will simply be called by its already well-established name of "hyperplane."

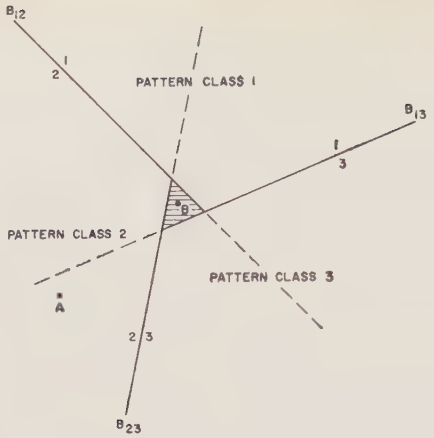

Fig. 3—Geometric representation of a linear decision function.

any of the three classes, and is hence rejected. This is not the normal sort of rejection due to an unreliable decision; rather it is a type of rejection inherent in a linear decision function.

One further comment is appropriate concerning the determination of which side of a hyperplane a point lies. Consider a hyperplane B represented by the set of points $\{x\}$ satisfying

$$\sum_{i=1}^{n} \alpha_i x_i + \alpha_0 = 0, \tag{4}$$

where

$$\sum_{i=1}^{n} \alpha_i^2 = 1. \tag{5}$$

The distance s from the hyperplane of a point with co-ordinates m_i, $1 \leq i \leq n$, is

$$s = \sum_{i=1}^{n} \alpha_i m_i + \alpha_0. \tag{6}$$

Hence, the distance of a point to the hyperplane (4) is simply given by substituting the coordinates of the point into the expression for the hyperplane (as in (6)), providing the expression is in a normalized form, that is, that (5) holds. The point is on one side of the hyperplane if (6) is positive, and on the other if (6) is negative. Which side of the hyperplane is to be positive or negative is completely arbitrary, since multiplication of (4) by -1 changes the sign of (6), but does not change the hyperplane.

Some Theorems Pertaining to Linear Decision Functions

One may rightly ask just why he should consider a linear decision function. Is there any guarantee that it will work? In general, this question can only be answered by designing the categorizer, and then deciding whether the resulting system is good enough. However, some confidence in linear decision functions may be obtained from the following theorem.

Theorem 1: For any categorizer based upon minimizing a Euclidean distance[3] to a set of reference points, there exists a categorizer based on a linear decision function which is at least as good. This includes categorizers which maximize a normalized cross-correlation function, and those which minimize a Hamming distance.

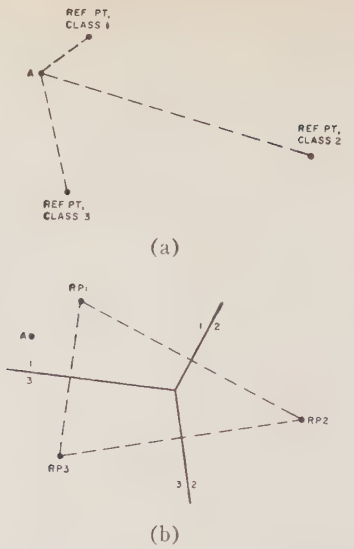

Fig. 4—The relation of a minimum distance categorizer to a linear decision function. (a) Minimum distance categorizer. (b) Linear decision function equivalent.

Proof: Fig. 4(a) illustrates a minimum distance categorizer. A measurement A is identified with the class represented by that reference point to which it is closest in a Euclidean sense. Consider reference points 1 and 2 (RP1 and RP2) and the hyperplane B_{12} which is the perpendicular bisector of the line segment joining RP1 and RP2 [Fig. 4(b)]. Then the statement that a point A is closer to RP1 than to RP2 is equivalent to the statement that the point lies on the 1 side of B_{12}. By constructing such a hyperplane for every pair of reference points, a linear decision function equivalent to the minimum distance decision function is obtained. Therefore, minimum Euclidean distance decision functions are a subclass of linear decision functions. (Sebestyen [23], [24] has considered non-Euclidean minimum distance decision functions, which are not a subclass of linear decision functions.)

It is well known that maximizing an appropriately normalized cross-correlation function or minimizing a Hamming distance is equivalent to minimizing a Euclidean distance.

The upper bound on the number of hyperplanes required for a linear decision function is determined by noting that, for every pattern class, there will be one hyperplane separating it from every other pattern

[3] If x and y are two points with co-ordinates x_i, y_i, $1 \leq i \leq n$, then the Euclidean distance s between x and y is

$$s = \left[\sum_{i=1}^{n} (x_i - y_i)^2 \right]^{1/2}.$$

class. If there are n pattern classes, there will then be $n(n-1)$ such hyperplanes. But this has counted each hyperplane twice. Therefore,

Theorem 2: For n pattern classes, a linear decision function comprises $n(n-1)/2$ hyperplanes.

It is shown in Highleyman [12] that not all the hyperplanes are always needed. Consequently, we will have occasion to refer to *complete linear decision functions*, in which all of the $n(n-1)/2$ hyperplanes are present, and *incomplete linear decision functions* in which some hyperplanes are not included.

Theorem 3: (Uniqueness) A complete linear decision function will classify any measurement into no more than one allowable pattern class.

Proof: Assume that a complete linear decision function has classified a measurement into both classes i and j. But because of the completeness criterion, this linear decision function contains a hyperplane B_{ij} which will indicate either that the point cannot belong to class i or that it cannot belong to class j (assuming that a point lying on a boundary is categorized according to some convention), thus contradicting the assumption. It has already been demonstrated that some measurements may not be classified into any of the allowable pattern classes by a linear decision function, complete or otherwise; these are the patterns which are rejected (see Fig. 3).

Theorem 4: The points in a measurement space which are identified with a particular class by a linear decision function form a convex set.[4]

Proof: This is proven in the theory of linear algebra [9].

The suggestion is sometimes made that perhaps a linear transformation on the measurement space may group like patterns closer together and separate unlike patterns, so that a linear decision function may perform better under the transformation than otherwise. That this is an invalid suggestion is demonstrated by the next theorem which is not proven here; its proof may be found in Highleyman [12].

Theorem 5: The categorization defined by a linear decision function is invariant under a nonsingular affine transformation[5] on the measurement space.

The Sequential Synthesis of a Linear Decision Function

Justification of Sequential Synthesis

The complete and accurate determination of a linear decision function requires the simultaneous determination of the several hyperplanes defining it. To see this more clearly, consider Fig. 5 in which a linear decision function categorizing three classes in a measurement space is illustrated. Let the closed curves shown in this figure represent, for purposes of discussion, the domains in measurement space of classes 1 and 2. In general, the losses associated with the various possibilities for misrecognition or rejection are different. Therefore, the boundary B_{12}, for instance, must be chosen so as to minimize the loss, given by (2), associated with various factors, such as:

1) The misclassification of members of class 1 into class 2 (the horizontally hatched area);
2) the misclassification of members of class 2 into class 1 (the vertically hatched area);
3) the misclassification of members of other classes into class 1;
4) the misclassification of members of other classes into class 2;
5) the rejection of members of various classes (the dotted area).

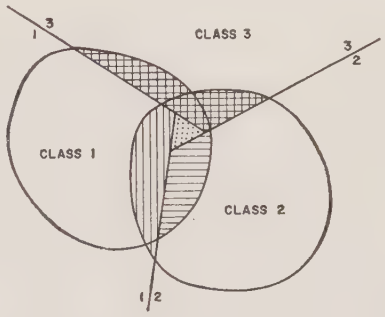

Fig. 5—Illustrating the requirement of simultaneous synthesis.

Note that the members of classes 1 and 2 which are already misclassified into other classes (in this case, into class 3 as illustrated by the cross-hatched area in Fig. 5) are not to be considered in the determination of the optimum B_{12}; these are members which are going to be misclassified anyway, regardless of the position of B_{12}. Therefore, in order to optimize B_{12}, the other boundaries, B_{13} and B_{23} in this case, must be known. But their determination also depends on B_{12}, by the same argument. Therefore, all of the boundaries comprising an optimum linear decision function must be determined simultaneously (simultaneous synthesis).

However, for a moderate number of allowable pattern classes n the number of hyperplanes $n(n-1)/2$ comprising a complete linear decision function becomes large, and the problem might easily become unmanageable. It would certainly be a more palatable procedure if each hyperplane could be determined independently of the others (sequential synthesis). In particular, consider a subotpimum linear decision function defined by a set of hyperplanes, one for each pair of the allowable pattern classes, in which each hyperplane is determined by minimizing the loss associated with the total confusion between the two particular classes which it separates. That this is usually a good approximation to the opti-

[4] A convex set is one in which a line segment joining any two points belonging to the set is contained within the set.

[5] A nonsingular affine transformation is a nonsingular linear transformation followed by a translation.

mum linear decision function is shown in Highleyman (12).

Even if it were deemed that this approximation is not good enough, the concept of sequential determination is still valid, for the approximation may be made better by an iterative process. First determine the hyperplanes independently, giving an initial linear decision function L_1. Then, only those members of each class which are correctly recognized by L_1 are used to recompute independently the hyperplanes, giving another linear decision function L_2. This process can be repeated until no significant improvement in performance is observed. Thus, to a better and better approximation, only those members of a particular pair of classes not misrecognized as belonging to some other class are used to determine the appropriate hyperplane. According to the previous argument, this then approaches the condition of simultaneous synthesis.

Upper Bound on the Expected System Loss, as Determined from the Constituent Hyperplanes

When one has determined a hyperplane B_{ij} one can associate with it an expected loss $C_{ij}(B_{ij})$, depending upon its performance in separating the two classes i and j, upon the loss coefficients c_{ij} and c_{ji} associated respectively with confusing the ith class with the jth class and vice versa, and upon the *a priori* probabilities ω_i and ω_j of occurrence of the classes i and j:

$$C_{ij}(B_{ij}) = \omega_i c_{ij} \int_{H_j(B_{ij})} \beta(m \mid s_i) dm + \omega_j c_{ji} \int_{H_i(B_{ij})} \beta(m \mid s_j) dm,$$

where

$$\int_{H_i(B_{ij})} \cdots dm$$

indicates integration over the half space which includes all points identified as class i by B_{ij}. It is of interest to relate the expected loss for the hyperplanes to the expected loss for the system; this relation is given by *Theorem 6*.

Theorem 6: The expected loss associated with a linear decision function is not greater than the sum of the expected losses associated with its constituent hyperplanes.

The proof to this theorem is given in Highleyman [12] and is burdensome and not particularly enlightening. In the hope that the theorem is easily accepted, the proof will not be repeated here.

A useful corollary follows:

Corollary: If the expected loss for each of the constituent hyperplanes of a linear decision function L is zero, then the expected loss for L is also zero.

Some Special Cases of Optimum Hyperplanes

It is shown in Highleyman [12] that, for the following two class problems, the optimum decision function is a linear decision function:

1) The two classes are equally probable *a priori*, have equal losses associated with misrecognition, and have probability distributions over the measurement space which are unimodal, spherically symmetrical, and identical except for a displacement of modes.
2) The two classes are equally probable *a priori*, have equal losses associated with misrecognition, and have probability distributions over the measurement space which are Gaussian and which have equal covariance matrices.
3) The convex hulls of the points in measurement space contained in each pattern class are nonintersecting.

The following theorem will be important later in the design and testing of practical machines.

Let us say that a set of q points in a space of n dimensions, where $q \leq n+1$, is *nondegenerate* if the points cannot be contained in a linear subspace of $q-1$ dimensions. In Fig. 6 are shown three nondegenerate points in two dimensions, and four nondegenerate points in three dimensions. Note that, in each case, the points can be separated into any two categories desired by an n-dimensional hyperplane. This is generalized in the next theorem, which is proven in Highleyman [12], but which should be intuitively acceptable from the above example.

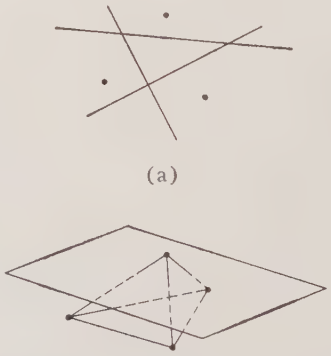

Fig. 6—Linear separability of nondegenerate points. (a) Two dimensions. (b) Three dimensions.

Theorem 7: Let S be a set of q nondegenerate points in an n-dimensional space, $q \leq n+1$. Let S_1 consist of any k of these points, and S_2 consist of the remaining $q-k$ points. Then S_1 and S_2 are linearly separable.

This theorem and the two following corollaries will be important later in the discussion of the practical interpretation and use of linear decision functions.

Corollary 1: Let S be a set of q points in an n-dimensional space such that any subset of S containing

no more than $n+1$ points is nondegenerate. Let $m \leq q \leq n+m-1$. Then S can be separated into m nonempty sets by a linear decision function.

Proof: By the corollary to *Theorem 6*, it is only necessary to show that each of the m sets is linearly separable. Let S be separated into the sets $S_1, \cdots, S_m$. Consider the case in which $q=n+m-1$, and the sets $S_1, \cdots, S_{m-1}$ each contain one point from S, leaving n points from S to comprise S_m. Then S_m and S_k, $1 \leq k \leq m-1$, are linearly separable by *Theorem 7*, since their union contains $n+1$ points. In any other possible case, the number of points contained in the union of any two sets S_i and S_j will be less than $n+1$, thus proving the corollary.

Corollary 2: Let S be a set of q points in an n-dimensional space such that any subset of S containing no more than $n+1$ points is nondegenerate. Let

$$q \leq \frac{mn}{2}, \qquad n \text{ even}$$

$$q \leq \frac{m(n+1)}{2}, \qquad n \text{ odd}.$$

Then S can be separated into m subsets each of size no greater than $(n+1)/2$ by a linear decision function.

Proof: The union of any two subsets will contain at most n nondegenerate points if n is even, $n+1$ nondegenerate points if n is odd. Therefore, each pair of subsets is linearly separable by *Theorem 7*, and the corollary is then proved by invoking the corollary to *Theorem 6*.

Determination of the Optimum Linear Boundary Separating Two Classes

This section will deal with the problem of determining the optimum (minimum loss) hyperplane which separates a pair of classes. In the general case, which is treated here, the loss associated with misrecognition of a member from one class is not necessarily the same as that loss for the other class. Recall, however, that when the losses are equal, then minimum loss corresponds to minimum error.

Three cases will be discussed. In the first, it is assumed that the pertinent conditional probability functions over the measurement space $\beta(m|s_i)$ are continuous, and that these probabilities and the *a priori* probabilities of occurrence ω_i are known. In the second case, it is assumed that nothing is known about the probabilities $\beta(m|s_i)$, and that the *a priori* probabilities ω_i may or may not be known. The determination of the optimum hyperplane is then based upon an appropriate sampling from the pattern classes. The third case is similar to the second case, but is applicable only when many independent measurements are made on the input pattern. Although it is a slightly more restrictive case, it leads to a better estimate of the hyperplane. The second and third cases are the cases of practical interest.

The Optimum Hyperplane for the Case of Known Distributions

Let $\beta(m|s_i)$ be the probability density function of class i over the measurement space, ω_i be the *a priori* probability of occurrence of class i, and c_{ij} be the loss associated with misidentifying a member of class i with class j. Denote a hyperplane which separates the classes i and j by B_{ij}, and let it be defined in the coordinate system $(x_1, \cdots, x_n)$ by the equation

$$x_1 = \sum_{k=2}^{n} \alpha_k x_k + \alpha_0. \tag{7}$$

Let $\nu(m|s_i, B_{ij})$ be the conditional probability density function of class i over the boundary B_{ij}:

$$\nu(m \mid s_i, B_{ij}) = \frac{\beta(m \mid s_i)}{\int_{B_{ij}} \beta(m' \mid s_i) dm'}$$

$\int_{B_{ij}} \cdots dm'$ denotes integration over the boundary B_{ij}. Define the weighted conditional probability density function of class i over the boundary B_{ij} by

$$\tau(m \mid s_i, B_{ij}) = c_{ij}\omega_i \nu(m \mid s_i, B_{ij}).$$

Theorem 8: The optimum linear boundary B_{ij}, separating two classes i and j which have weighted conditional proability density functions over B_{ij} given by

$$\tau_i = \tau(m \mid s_i, B_{ij})$$

$$\tau_j = \tau(m \mid s_j, B_{ij}),$$

must satisfy the following conditions:

1) The integrals of τ_i and τ_j over B_{ij} must be equal.
2) The means of τ_i and τ_j must be equal.

Proof: Let B_{ij} be oriented such that the half-space identified as class i corresponds to

$$x_1 < \sum_{k=2}^{n} \alpha_k x_k + \alpha_0.$$

The expected loss is then

$$C(B_{ij}) = c_{ij}\omega_i \int_{-\infty}^{\infty} dx_n \cdots \int_{-\infty}^{\infty} dx_2 \int_{\sum_{k=2}^{n} \alpha_k x_k + \alpha_0}^{\infty} \beta(m \mid s_i) dx_1$$

$$+ c_{ji}\omega_j \int_{-\infty}^{\infty} dx_n \cdots \int_{-\infty}^{\infty} dx_2 \int_{-\infty}^{\sum_{k=2}^{n} \alpha_k x_k + \alpha_0} \beta(m \mid s_j) dx_1. \tag{8}$$

We wish to find the coefficients of the hyperplane B_{ij} which correspond to extreme points of (8). First differentiate (8) with respect to α_0:

$$\frac{\partial C(B_{ij})}{\partial \alpha_0} = -\int_{B_{ij}} \tau_i dm + \int_{B_{ij}} \tau_j dm = 0,$$

which is condition 1 of the theorem. Next, differentiate (8) with respect to α_k, $2 \leq k \leq n$:

$$\frac{\partial C(B_{ij})}{\partial \alpha_k} = -\int_{B_{ij}} x_k \tau_i dm + \int_{B_{ij}} x_k \tau_j dm = 0,$$
$$2 \leq k \leq n.$$

A similar expression may be obtained for $k=1$ by rewriting (7) and thus (8) in terms of some other coordinate. This set of conditions, *i.e.*, for $1 \leq k \leq n$, corresponds to condition 2 of the theorem.

In general, there will be several hyperplanes satisfying the conditions of *Theorem 8*. Some of these will correspond to maxima of $C(B_{ij})$, others to minima. These must then be searched to determine which corresponds to the absolute minimum of $C(B_{ij})$.

The Optimum Estimate for the Hyperplane for the Case of Unknown Distributions

We will now assume that the designer has no knowledge concerning the form of the probability function $\beta(m|s_i)$, but he may or may not know the *a priori* probabilities ω_i. We will assume the existence of all such probabilities and probability functions, whether known or not.

If a hyperplane B_{ij} is passed through M such as to divide classes i and j in some fashion, then a certain portion of the members of classes i and j will be misidentified by B_{ij}. Let p_i be the probability of misidentification of a member from class i, given B_{ij} and a member of class i (p_i is the integral of $\beta(m|s_i)$ over the half-space on the j side of B_{ij}). Then the conditional loss associated with B_{ij} (see (1)) is

$$\tilde{C}(B_{ij}) = c_{ij}\omega_i' p_i + c_{ji}\omega_j' p_j$$
$$= c_{ij}e_i + c_{ji}e_j,$$

where

$$\omega_i' = \frac{\omega_i}{\omega_i + \omega_j}, \qquad \omega_j' = \frac{\omega_j}{\omega_i + \omega_j},$$

and $e_i = \omega_i' p_i$ is the probability of misrecognition, given B_{ij}, of a member from class i when patterns are chosen randomly from classes i and j according to ω_i' and ω_j'.

Theorem 9: Construct a hyperplane B_{ij} in the measurement space M which divides M into two half spaces, all the points in one being identified as class i, the points in the other being identified as class j. Consider two sampling procedures designed to estimate the conditional cost $\tilde{C}(B_{ij})$:

1) The *a priori* probabilities ω_k are unknown. Let it be assumed that there exists a pattern source which will generate patterns from classes i and j randomly according to ω_i' and ω_j'. Draw a pattern from this source, identify it, and then determine the identification according to B_{ij}. This latter identification will either be in error or will be correct. Repeat this experiment m times. Let e_i be the number of samples from class i which are misidentified by B_{ij} as class j, and likewise for e_j.
2) The *a priori* probabilities ω_k are known. Take m_i samples from class i and m_j samples from class j such that

$$m_i = \omega_i' m$$
$$m_j = \omega_j' m. \tag{9}$$

(It will be assumed that ω_i' and ω_j' are such that (9) can be met exactly.) Identify each of these m samples according to B_{ij}. Let e_i be the number of samples from class i misidentified by B_{ij} as class j, and likewise for e_j.

Then the maximum likelihood estimate in either case for the conditional loss, $\hat{\tilde{C}}(B_{ij})$, is

$$\hat{\tilde{C}}(B_{ij}) = \frac{c_{ij}e_i + c_{ji}e_j}{m}. \tag{10}$$

The proof is based on the fact that m_i and m_j are binomially distributed. Since the theorem is intuitively acceptable, the proof is not given here, but may be found in Highleyman [12].

If we take samples from a pair of classes according to either sampling procedure, there will be a set of hyperplanes (infinite in number) which will minimize the maximum likelihood estimate of the conditional loss (10). It is quite reasonable, then, to choose one of the hyperplanes from this set as the estimate of the optimum hyperplane separating the two classes. That is, it is clear from (10) that *we will search for a hyperplane which will minimize the loss associated with the sample points.* This is also intuitively quite reasonable.

Note that *Theorem 9* and the resulting procedure is independent of the probability functions over the measurement space. Hence, one need make no assumptions concerning the form of these functions, nor need one concern himself with the dependencies between the various measurements.

A Computation Algorithm for the Case of Unknown Distributions

In this section will be outlined an iteration algorithm which will be useful for determining that boundary which minimizes the maximum likelihood estimate of the conditional loss for the boundary. The detailed iteration equations are given in Highleyman [12]. There has been some work by others concerning similar boundaries when the measurement space is a binary space [17], [18], [26], [27], or when the classes are Gaussian distributed in measurement space (discriminant functions [2], [7], [25] yield a good approximation for this case).

Fig. 7(a) illustrates this problem for two classes, k and l. Samples from class k are shown by crosses, from class l by circles. A boundary B_{kl} is indicated. Let us number these samples from 1 to m, there being a total of m

samples, and define a weight T_j' for the jth sample point $1 \leq j \leq m$ such that

$T_j' = 0$ if the point is on the correct side of B_{kl};
$T_j' = c_{kl}$ if the point represents a sample from class k on the l side of B_{kl};
$T_j' = c_{lk}$ if the point represents a sample from class l on the k side of B_{kl}.

It is clear, then, that minimizing the estimate of the conditional loss (10) is equivalent to minimizing

$$T'(\alpha_i) = \sum_{j=1}^{m} T_j' \tag{11}$$

where the α_i, $0 \leq i \leq n$, are the coefficients of the hyperplane B_{kl} defined by (4).

$T'(\alpha_i)$ is an $(n+1)$-dimensional function for a system with n measurements. A convenient way to determine a minimum point of this function would be to use a gradient method, such as the method of steepest descent [1], [4], [20]. However, $T'(\alpha_i)$ is a discontinuous function of the α_i, and thus has no meaningful gradient.

However, it is possible to approximate T_j' by some function $T_j(s_j, \lambda)$ which is continuous everywhere, and which has the property

$$\lim_{\lambda \to \infty} T_j(s_j, \lambda) = T_j'$$

where T_j is written as a function of the distance of the jth point from the hyperplane to emphasize this continuous dependence. Such a function is shown in Fig. 7(b), in which s_j is the distance of the jth point from the boundary B_{kl}, and will be considered to be positive if the point j is on the correct side of the boundary. The quantity c_j in Fig. 7(b) is equal to c_{kl} if the jth point represents a member from class k; $c_j = c_{lk}$ otherwise. If the function

$$T(\alpha_i, \lambda) = \sum_{j=1}^{m} T_j(s_j, \lambda) \tag{12}$$

were to be minimized for some finite λ with respect to the α_i, and then λ increased and (12) minimized again, and this process repeated, one would expect the hyperplane to converge to one of the set of hyperplanes minimizing (11). This minimization process can now make use of the method of steepest descent.

There are many functions which would be suitable for $T_j(\lambda)$. One convenient one is the cumulative Gaussian distribution with zero mean and standard deviation $1/\sqrt{2\lambda}$; it will be denoted $G(\lambda s_j)$. Thus

$$T_j(s_j, \lambda) = c_j[1 - G(\lambda s_j)], \tag{13}$$

where

$$\frac{\partial[G(\lambda s_j)]}{\partial s_j} = \frac{\lambda}{\sqrt{\pi}} e^{-(\lambda s_j)^2}.$$

The algorithm then consists of determining the direction of the gradient of (12), using some suitable function for $T_j(s_j, \lambda)$ such as (13). Some reasonable initial guess for the hyperplane and some value for λ are used as a starting point. The approximate minimum of (12) is determined by the method of steepest descent, and the process is then repeated with a larger value of λ. When the desired accuracy is achieved, the iteration is terminated.

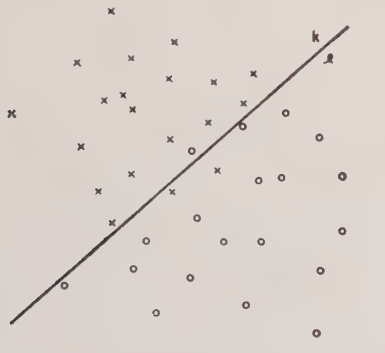

Fig. 7—Illustrating the iterative algorithm.

A Computational Algorithm for the Case of Many Independent Measurements with Unknown Distributions

We next consider the case of a large number of independent measurements whose distributions are otherwise unknown. The distances of members of pattern class i from a given hyperplane may be said to be distributed according to a probability density function $\eta_i(s)$. $\eta_i(s)$ is in general unknown. However, in many cases, one may estimate it quite accurately by the following argument.

Recall that the distance of a point m from a hyperplane is given by

$$s = \sum_{i=1}^{n} \alpha_i m_i + \alpha_0,$$

where m_i is the ith coordinate of the point (the ith measurement), and the α_i are the normalized coefficients of the hyperplane. But m_i is a random variable, and hence, if n is large, s is a weighted sum of a large number of random variables. If the dependencies between the random variables are weak, one may then reasonably expect from the Central Limit Theorem [8] that the distribution of s is approximated by a normal distribution. Of course, if the measurements m_i are independent and normally distributed, then the normality of s follows immediately for any n.

Consequently, $\eta_i(s)$ is, to a good approximation in many cases, a normal density function. Its mean and variance can be easily estimated from the samples which are to be used to design the linear decision function. Using this normality concept, one can develop an algorithm for estimating the optimum hyperplane separating the two classes. We are interested in choosing that hyperplane that minimizes the estimate of the expected error, or confusion, between the two classes. However, it is possible to estimate the error associated with a hyperplane by estimating the normal distribution of the distance of the members of each class from the hyperplane, and determining the area under the tails of these two distributions falling on the wrong side of the hyperplane. This might be expected to be a better estimate of the error than the proportion of points misrecognized, since more information is used in the estimate, *providing the assumption of normally distributed distances is valid.*

Consequently, it would be quite reasonable to choose, as an estimate of the optimum linear boundary, that hyperplane which minimizes the normal estimate of error rather than the estimate based on the proportion of misclassified samples, providing again that the assumption of normality holds. A computational algorithm based on minimizing this normal estimate of error, using the method of steepest descent, is developed in Highleyman [12], where confidence intervals for this and the preceding estimate are also developed. These confidence intervals illustrate that this latter estimate is indeed the better of the two. Note that the resulting hyperplane for each local minimum is unique, in contrast to the previous algorithm in which the hyperplane could be any one chosen from, in general, an infinite set.

An Example of Categorization

To show the relation between these various approaches to the problem of categorization (the optimum decision function, the optimum linear decision function based on knowledge of the distributions, and the optimum linear decision function based on sampling), the following two-class problem was solved using each technique.

Problem: There are two pattern classes, 1 and 2, upon which two measurements, x and y, are made. The measurements are independent and normally distributed with the following parameters:

$$\begin{aligned} \text{Class 1:}\quad & \sigma_{1x} = 1 \qquad \mu_{1x} = 1 \\ & \sigma_{1y} = 0.5 \qquad \mu_{1y} = 1 \\ \text{Class 2:}\quad & \sigma_{2x} = 0.1 \qquad \mu_{2x} = 2 \\ & \sigma_{2y} = 2 \qquad \mu_{2y} = 0 \end{aligned}$$

The *a priori* probabilities of occurrence and the misrecognition losses are the same for each class. Determine the boundaries between the classes in the measurement space x, y.

In Fig. 8 are shown the 1δ contours of the classes 1 and 2. Also shown are the boundaries based on the previously mentioned approaches:

1) The optimum decision function for the two-class Gaussian case is well known [2], [16]. The result is the hyperbolic boundary shown, given by the equation

$$-99x^2 + 3.75y^2 + 398x - 8y - 393 = 0.$$

The region identified as class 2 is that between the two curves of the hyperbola.

2) The optimum linear decision function, given complete knowledge of the distributions, is worked out for this case in Highleyman [12], and is based on the use of *Theorem 8*. The result is

$$y = 1.04x - 1.32. \tag{14}$$

This is shown as the "theoretical" linear boundary in Fig. 8.

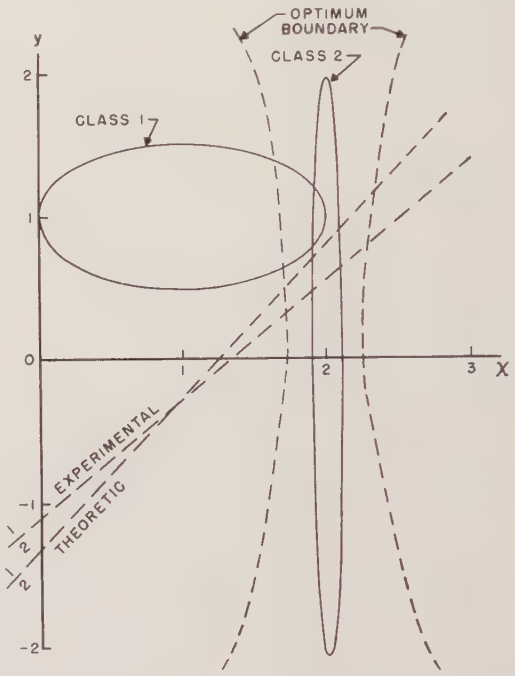

Fig. 8—An example of some of the approaches to categorization.

3) The optimum linear decision function based on sampling was determined using the first iteration algorithm (normally distributed distances were not assumed, although in this case they are normally distributed). A random number generator was programmed for the IBM 7090 digital computer which generated numbers according to the above distributions.

One hundred sample points were taken from each class, and various initial boundaries were tried:

$$x = 1$$

$$x = 2.5$$

$$y = x - 1$$

$$y = 4.2x - 6.8.$$

Each of the final boundaries were slightly different, but the important point is that each one categorized the points in exactly the same manner. (Thirty-nine points were always misclassified.) An example of one of the final boundaries is

$$y = 0.816x - 1.11 \tag{15}$$

which is plotted in Fig. 8 as the linear boundary marked "experimental." Compare (14) to (15); the difference illustrates the sampling error.

Experimental Application—The Recognition of Hand-Printed Numbers

The recognition of hand-printed numbers was attempted with a linear decision function. The set of measurements which was used involved quantizing the number into a 12×12 binary matrix. A matrix element was given a weight of one if it contained a mark and a weight of zero if it contained no mark. The quantized number was then positioned in the matrix by aligning its center of gravity with the center of the matrix. Hence, a 144-dimensional binary measurement space was used. This set of measurements is a rather unsophisticated set in that the measures are not at all invariant within a particular class; thus, one would not be too surprised if a linear decision function did not perform very well.[6] However, the attempt is still interesting since it will allow the testing of the preceding ideas in some detail.

Estimating the Linear Decision Function

The data used to estimate the optimum linear decision function was gathered in the following manner. A subject was asked to print neatly the ten numbers on a piece of quadruled paper at a size approximating the ruled boxes. Fifty different people were asked, resulting in a sample size of 50 for each of the ten pattern classes. These data were then automatically reduced to a 12×12 matrix (encoded on IBM punched cards) by an optical matrix scanner constructed by the author.[7]

In Fig. 9 is shown an example of some of this design data, illustrating approximately the range of size and neatness obtained. In Fig. 10 are shown examples of some of the quantized numbers.

Forty-five hyperplanes are required in the complete linear decision function categorizing the ten numbers. It was assumed that all losses due to misrecognition are equal (minimum error), and that all *a priori* probabilities are equal. Each hyperplane was determined by first finding a hyperplane which correctly categorized the maximum number of sample points (according to the first computational algorithm), and then by "trimming up" that hyperplane so that the normal estimate of error was minimized (according to the second computational algorithm). About 35 seconds, on the average, was required to determine a hyperplane, given an initial position.

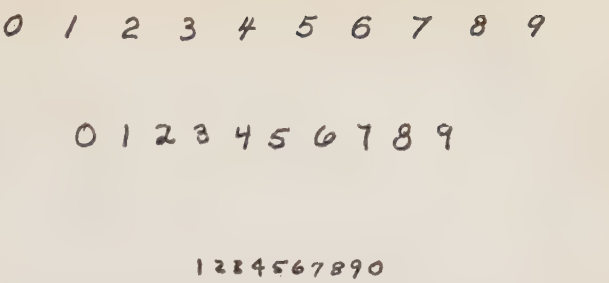

Fig. 9—Some examples of the hand-printing design data.

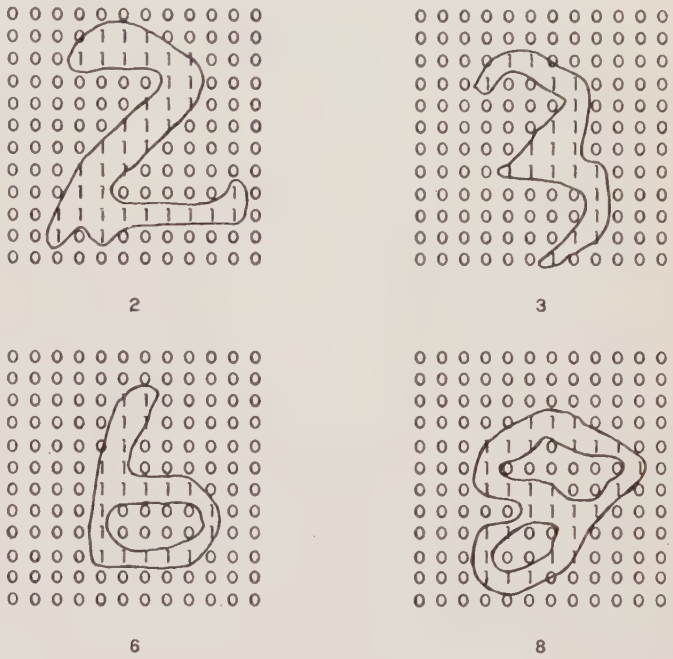

Fig. 10—Examples of quantized forms of the hand-printed numbers

For each pair of pattern classes, four initial hyperplanes were tried. One of these was that hyperplane which was the perpendicular bisector of the line segment joining the means of the two classes. The other three initial hyperplanes were parallel to this one (*i.e.*, the direction cosines were the same) and corresponded to an α_0 of 0, -5 and $+5$. Each of these initial conditions led to a hyperplane better than any of the other initial conditions in at least one of the 45 cases, thus illustrating the importance of trying several initial hyperplanes.

In Fig. 11 is shown the estimated optimum hyperplane B_{21} which separates the numbers 2 and 1. The coefficients α_i, $1 \leq i \leq n$, are shown arranged in a matrix corresponding to the receptor matrix. The positive side of B_{21} corresponds to the number 2. One

[6] A very effective set of measurements has been proposed by Kamentsky [15] for the recognition of hand-printed numbers. This involves using a "flying-polar" scan which is capable of determining the number of closures and cusps (partial closures) and the orientation of cusps in a character.

[7] These are the same data used in the Bledsoe-Browning comparison, reported in Bledsoe [3], and Highleyman and Kamentsky [11].

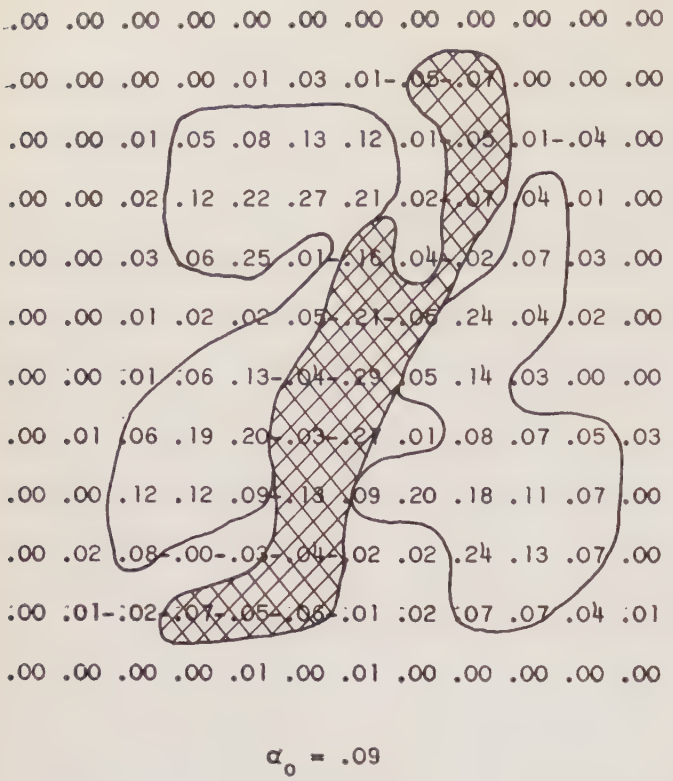

Fig. 11—The hyperplane B_{12}.

would then expect that those coefficients which corresponded to matrix elements in which a mark from a two was likely to occur and a mark from a one was not likely to occur would be weighted positively, and vice versa for those elements in which a mark from a one is more likely to occur. Contours are drawn around regions of large positive and negative weight in Fig. 11, and the negative regions are shaded. One sees that the above intuitive observation does indeed hold.

The resulting linear decision function miscategorized five patterns (1.0 per cent) and rejected one pattern (0.2 per cent) of the total design sample of 500, as shown in the confusion matrix of Table I (the *R* column indicates the input patterns rejected by the inherent rejection of the linear decision function). Also shown in the table are the values of the error-rate estimates based on the normality assumption. However, one cannot conclude that these percentages are any sort of valid estimate for the performance of the system, since they are based on the samples used to design the system. In fact, since only 100 points are being separated in 144 dimensions by each hyperplane, one might expect from *Theorem 7* that the linear decision function ought to do well on the design data. The saving grace here is the fact that the measurement space is binary, and therefore the sample points are highly degenerate in the sense of *Theorem 7*. It is therefore not to be expected

TABLE I

Input Class	Recognized As: 0	9	8	7	6	5	4	3	2	1	*R*
0	50 —	0.004	0.000	0.014	0.021	0.005	0.010	0.009	0.005	0.000	—
9	0.004	48 —	1 0.030	1 1.118	0.003	0.001	1.686	0.001	0.044	0.000	—
8	0.000	0.184	50 —	0.005	0.038	0.033	0.133	0.296	0.034	0.007	—
7	0.026	0.236	0.001	50 —	0.000	0.000	0.003	0.022	0.111	0.061	—
6	0.024	0.005	0.052	0.000	50 —	0.018	0.024	0.029	0.136	0.000	—
5	0.002	0.002	0.033	0.000	0.067	50 —	0.011	0.068	0.002	0.000	—
4	0.004	1.771	0.039	0.011	0.013	0.009	50 —	0.002	0.032	0.000	—
3	0.003	0.001	2 0.694	0.042	0.026	0.152	0.001	47 —	1 0.894	0.010	—
2	0.017	0.041	0.034	0.037	0.157	0.003	0.027	1.990	49 —	0.002	1 —
1	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.003	0.003	50 —	—

Correct 494 (98.8%)
Error 5 (1.0%)
Reject 1 (0.2%)

Confusion matrix for the design sample: Upper numbers give the categorization of the design data; lower numbers give the normal estimates of error, in per cent.

that any set of points, no greater in number than $n+1$ (145 in this case), will be linearly separable in general in this measurement space.

Testing the Linear Decision Function

The resulting system was tested with 120 additional samples (12 samples of each number) gathered in the same manner as the design data. Fig. 12 shows this test sample. The confusion matrix of Table II represents the categorization of these samples.

The resulting estimate of the system error rate, rejection rate, and correct recognition rate, from the results shown in Table II, are 19.2 per cent (23 points), 19.2 per cent (23 points) and 61.6 per cent (74 points), respectively. From confidence intervals given in Highleyman [12] covering this sort of test, one can then state that, with probability 0.95, the intervals 0.13–0.28, 0.13–0.28, and 0.52–0.70 include the system error probability, rejection probability, and correct recognition probability, respectively.

It is not surprising to find the estimated performance of this linear decision function to be so poor. This can be blamed on two factors: 1) a poor choice of measurements, inthat the measurements used were very dependent upon the distortions and various noise effects (smudging, etc.) which might occur, and 2) a design sample size which is too small, leading to a poor estimate of the optimum hyperplanes. This latter point is emphasized by the difference in the results obtained with the design sample and with the test sample (98.8 per cent recognition vs 61.8 per cent). If the design sample were sufficiently large, one would expect the results based on the two samples to be comparable; hence, one might expect that, for a large design sample size, the performance of the resulting machine would be somewhere between the two results obtained herein. However, this is not so important, since this experiment was not meant to result in the design of a practical character recognition machine, but was rather meant to test certain aspects of the theory previously developed.

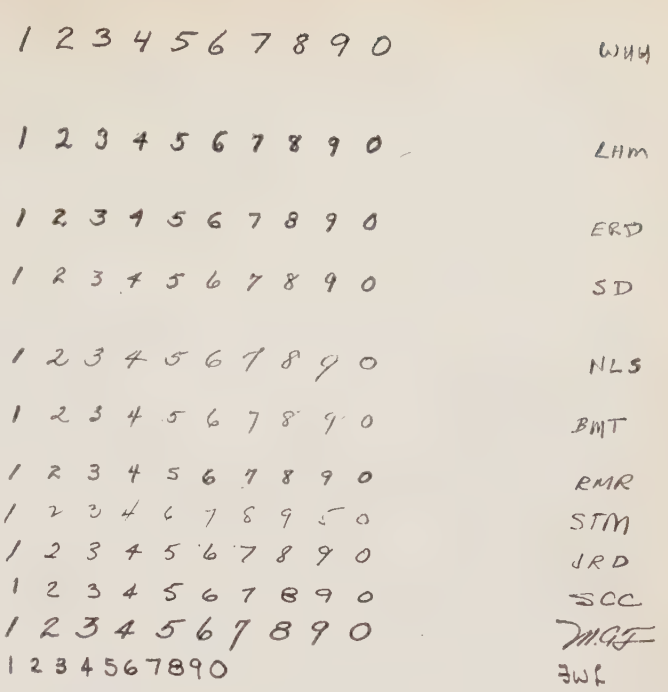

Fig. 12—The test sample.

TABLE II

Input Class	Recognized As: 0	9	8	7	6	5	4	3	3	1	R
0	9										3
9		6		1			1				4
8	1		5					2		1	3
7		1		8			2				1
6					8	1					3
5	1					8		2			1
4		3			2		4				3
3						2		9			1
2				2	1				6		3
1										11	1

Correct 74 (61.6%)
Error 23 (19.2%)
Reject 23 (19.2%)

Confusion matrix for the test sample.

Conclusion

This paper has discussed the properties and design of a particular class of categorizer, the linear decision function, which is of practical interest for two reasons:

1) It can be empirically designed without making any assumptions whatsoever about either the distribution of the receptor measurements or the *a priori* probabilities of occurrence of the pattern classes, providing an appropriate pattern source is available.
2) Its hardware realization is quite economic.

It is not guaranteed that a linear decision function will always perform well, although it is guaranteed that it will perform better than (or at least as well as) the minimum distance categorizer which is popular in the present-day art. Nor is it a simple matter to predict in advance whether a linear decision function has a chance of working (this problem is discussed in Highleyman [13]).

Consequently, if one is interested in a linear decision function type of categorizer, his best approach is actually to design the categorizer and estimate its performance. If the estimated performance is good enough, then the designer has succeeded in designing an economic categorizer. If the performance is not good enough, the designer has two choices:

1) Search for a better set of measurements, a set which is more invariant to the natural perturbations of patterns contained within a class (the results of the experiment on hand-printing illustrate the importance of invariant measurements); or
2) go to a different type (usually a more complicated type) of categorizer.

One area which has not been discussed in this paper is the problem of minimizing a linear decision function. It often happens that not all of the hyperplanes are needed, *i.e.*, some may fall outside of the convex regions determined by the others. The linear decision function may also be used to detect redundancy in the measurements. This problem is discussed further in Highleyman [12], where it is experimentally shown that the linear decision function for the hand-printing case discussed herein may be reduced from 144 measurements and 45 boundaries to 110 measurements and 39 boundaries.

Acknowledgment

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Gross Errors in Height Indication from Pulsed Radar Altimeters Operating over Thick Ice or Snow*

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Summary—**Errors reported in 1946 by aircraft pilots using pulsed radar altimeters over Antarctic ice, coupled wih results of radio-wave propagation studies in both polar areas (1946–1955), led to measurements of the electrical characteristics of thick ice at high and ultra-high frequencies. These measurements produced information relative to dielectric constants, loss factors, scattering, and interface reflection data that subsequently permitted successful radio-wave penetration measurements in continental ice to depth of several hundred feet in both the Antarctic and the Arctic (1958–1960). Results indicated clearly that low-flying pilots relying on pulsed 440-Mc altimeters in poor visibility over thick ice can be fatally misled by errors inherent in these instruments. The paper presents recent data obtained by the Signal Corps pertinent to radio-wave transparency of thick ice and snow.**

Historical Background

THE FIRST evidence of the transparency of ice and snow to HF radio waves was witnessed at Little America in 1933. At that time, bare-copper antenna transmission lines several hundred feet long, spaced only 10 inches apart on 800-ft-thick floating ice and buried under several feet of snow, operated successfully for months. These and other similar experiences were repeated and supplemented 13 years later during Operation Highjump (1946–1947).[1] Parallel phenomena were being observed concurrently over deep permafrost areas in northern North America in a two-year wave-propagation study conducted near Hudson Bay. This program showed, among other things, that 100-Mc signals traveled from $1\frac{1}{2}$ to $2\frac{1}{2}$ times as far over frozen soil as they did over temperate zone terrain (with antennas of the same height).

In 1955 when building activities started at the IGY's first Antarctic research base on the Ross Ice Shelf (Little America V), the Signal Corps' Antarctic Research Team began southern operations. Measurements of the dielectric constants, loss factors, and conductivities of thick ice were made at 30 Mc at 1-ft intervals to depths of 30 ft. Simultaneous horizontal propagation studies carried out between points a mile apart, both above and below the ice surface at 40 to 440 Mc showed[2] small finite attenuations for horizontally polarized waves and indicated ducting in snow strata while losses suffered by vertically polarized waves increased rapidly with depth. In December two 440-Mc pulsed-type radar altimeters were obtained and the first intentional vertical transmission through ice was made on the Ross Shelf where the ice was 800 ft thick and floated on a half a mile of sea water. Although results were negative, a second set of measurements made on 500-ft-thick landborne ice in January, 1958, at Wilkes Station (south of Australia) resulted in high-amplitude reflections in at least three locations that corresponded with seismic soundings made at the same spot six months later. The Wilkes soundings proved that pilots flying low over 500-ft-thick ice would read 900 ft of altitude when the plane's wheels were about to hit the surface. The Signal Corps' Antarctic Research Team reported its results to international scientists at an IGY Symposium in Wellington, New Zealand, in February, 1958.

Field Measurements, Greenland, 1959–1960

In August, 1959, two modified 440-Mc altimeters were used in Greenland when it had become known that although computations had shown that the bottom of mile-deep ice should be attainable with these instruments, the real problem lay in determining the gradients with depth of dielectric constant and loss tangent. This was simplified when 440-Mc soundings made on the three-mile-wide ice-ramp approach to the western edge of the Greenland icecap (Fig. 1) agreed almost exactly with a seismic profile (produced by the Engineer Corps) which showed that the ice tapered from 860 ft three miles inland to zero at the western edge and gave precise surface elevations. The dielectric-constant value utilized in Greenland was the same as that previously employed in the Antarctic,[3] *i.e.*, 3.2. Thus, no apparent change was found to occur in dielectric constant value with variations in pressure as ice depth decreased from 860 to less than 150 ft (where radar pulse lengths precluded shallower measurements). Results of the earlier Antarctic soundings coupled with those on the Greenland ramp, and subsequent icecap measurements that gave accurate depths down to 1100 ft, proved that 440-Mc radar altimeters give seriously false altitude readings when employed near the surface of thick ice (Figs. 2–4).

During the summer of 1960, measurements were made over ice of known depths from the surface and from aircraft at 110, 220, 440, and 4300 Mc. These showed that frequencies of 110 Mc and lower were optimum for sounding activities, whereas those of 4300 Mc and higher were better for altimetry.

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[1] "Report of Operation Highjump," U.S.N., Naval Aviation Operations Sections, Washington, D. C.; July, 1947

[2] A. H. Waite, "Report of Operation DEEPFREEZE I and II," USASEL TM-M-1794 and TM-M-1874; 1955–1956 and 1956–1957.

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Fig. 1—Portion of ice-ramp at Tuto, Greenland. Ice is 860 ft thick at summit and rests on rock of varying composition.

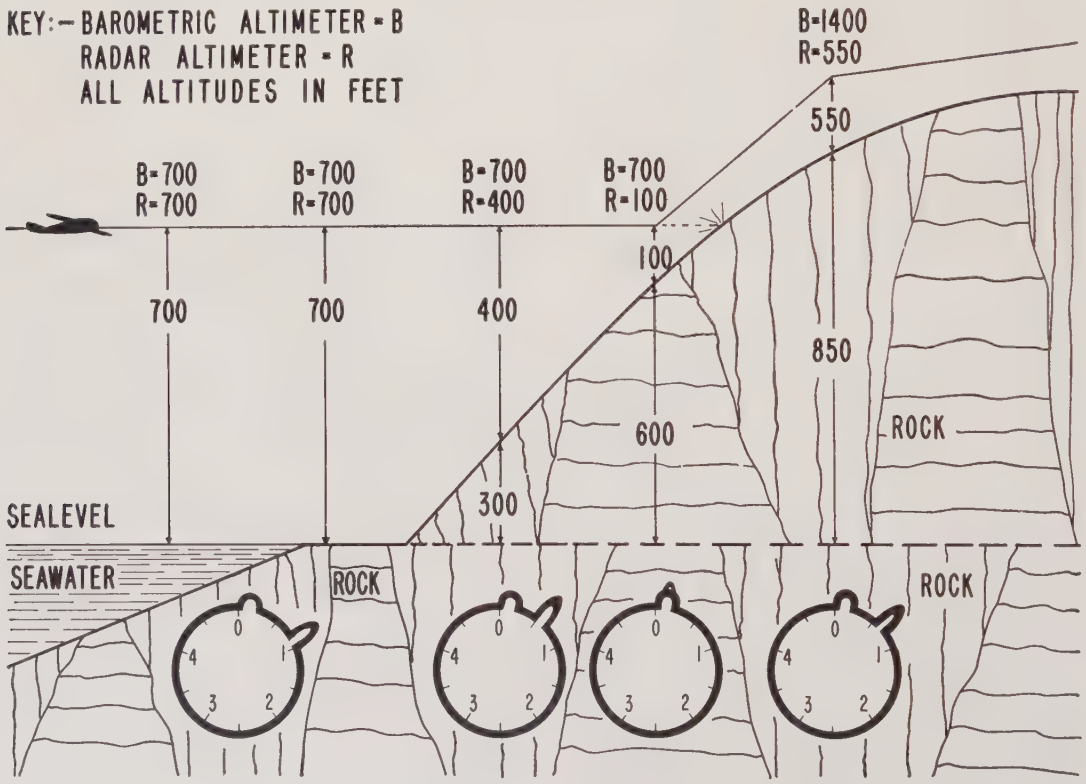

Fig. 2—Typical behavior of barometric and radar altimeters when flown over water and rocky soil. Plane's flight-path is shown 700 ft high until obstacle is approached, when flight path is altered upward. Note normalcy of both barometric and radar altimeters. Reflection coefficient (above 100 kc) for air to rock is 52 per cent.

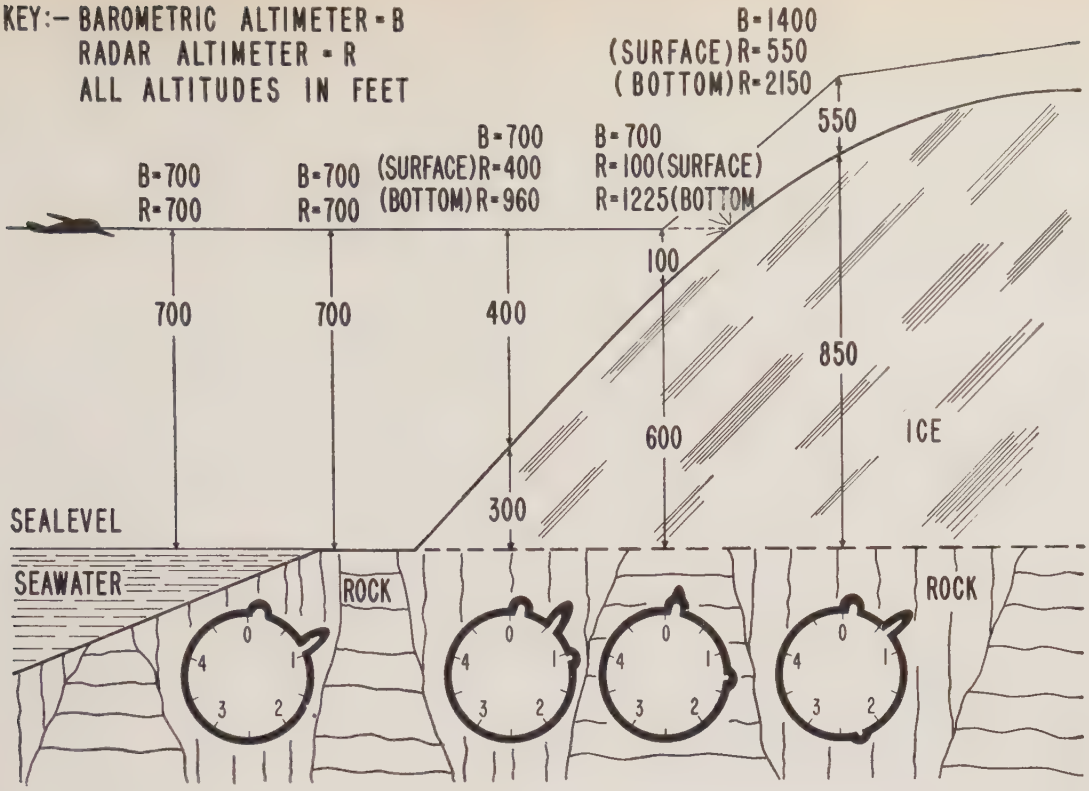

Fig. 3—Typical behavior of barometric and SCR-718 radar altimeters when flying over water, rock, and thick ice. Barometric altimeter remains normal, but, when over ice, radar altimeter shows one pip for surface and one for bottom. See Fig. 4 and text.

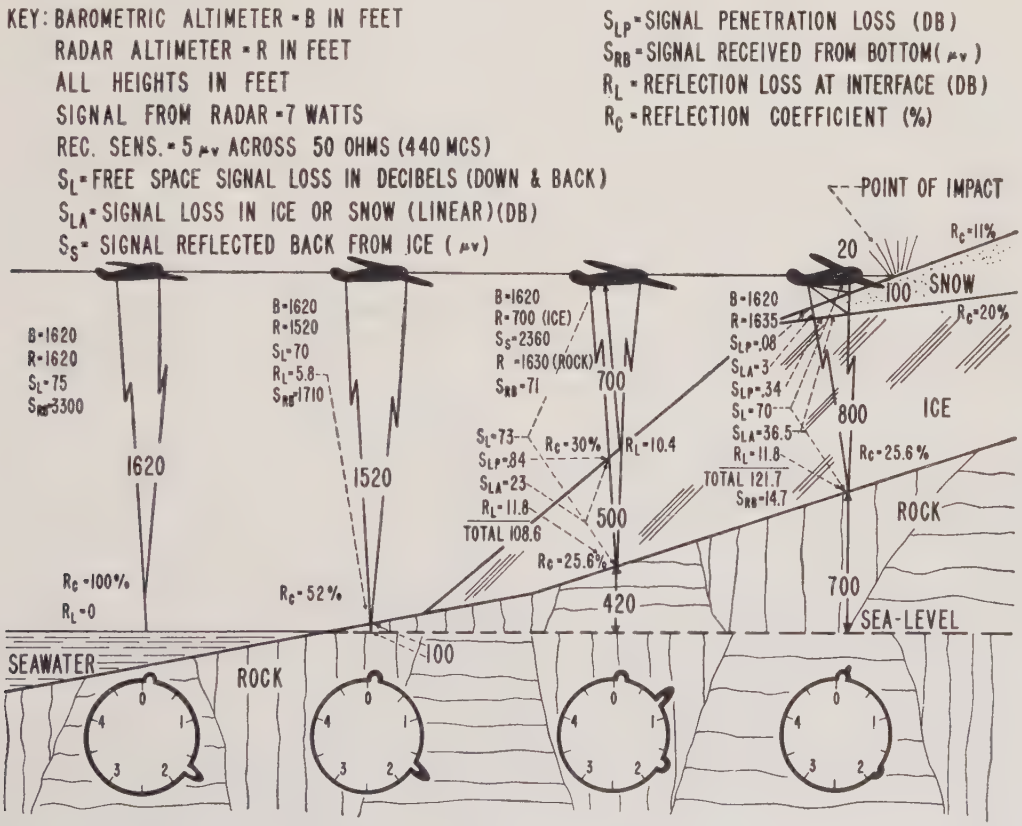

Fig. 4—Computed signal losses for a typical flight over water, rock, thick snow and ice. This curve shows signal strength losses (db) at air/snow, air/ice, snow/ice, and ice/rock interfaces, and those in the medium itself, as well as the computed values of signal strength returned to SCR-718 receiver in each case illustrated (microvolts). All computations are based on the 7-watt peak power of the 440-Mc SCR-718. Receiver sensitivity is approximately 5 μv across 50 ohms and system gain is 130 db.

Propagation Through Ice and Altimeter Correction Factors

The propagation of any radio wave through one or more media involves basic free-space losses, which are functions of distance, antennas, and frequency, but are independent of the media themselves, and the attenuations suffered through absorption, reflection, and scattering. Changes in velocity that affect radar altimeter indicators (operating over thick ice) are attributable to variations in the density and hence the dielectric constant of the media concerned.

Free-Space Attenuation

Utilizing special antenna and equipment installations employed throughout the 440-Mc studies, we can summarize "free-space loss" by the expression

$$S_L = 15 + 20 \log D \text{ (in db)} \tag{1}$$

where D is the total signal path-length in meters.

Attenuation Due to Absorption

The amount of absorption in a medium is directly expressed by the loss tangent, tan δ, of that medium. It is also directly affected by the dielectric constant, ϵ, and inversely by the wavelength, λ. Generally, the loss in the medium due to absorption is equal to[3]

$$S_{LA} = 8.686 \frac{2\pi}{\lambda}\left[\frac{\epsilon}{2}\left(\sqrt{1+\tan^2\delta}-1\right)\right]^{1/2} \text{db/m.} \tag{2}$$

When the loss tangent is very small, as at 440 Mc, the frequency of interest in snow and ice, this expression reduces to

$$S_{LA} = \frac{8.686\pi\sqrt{\epsilon}\tan\delta}{\lambda} \text{ db/m.} \tag{3}$$

For hard ice, when $\lambda = 0.681$ meter, tan $\delta = 0.001$,[3] and $\epsilon = 3.5$,[4] the loss becomes 0.075 db/m.

For snow, $\lambda = 0.681$, tan $\delta = 0.0003$,[3] and $\epsilon = 1.56$,[4] and the loss is 0.015 db/m.

Attenuation Due to Reflection

For reflection losses, the only case of interest is vertical incidence (where $\psi = 90°$, ψ being the angle that a radiated signal from an airborne altimeter makes with the ice surface or rock bottom beneath the aircraft). The reflection coefficients for vertically and horizontally polarized waves are equal in magnitude and may be written

$$|R_c| = |R_{v,h}e^{j\phi_{v,h}}| = \frac{\dfrac{\sqrt{\epsilon_2 - j60\sigma_2\lambda}}{\sqrt{\epsilon_1 - j60\sigma_1\lambda}} - 1}{\dfrac{\sqrt{\epsilon_2 - j60\sigma_2\lambda}}{\sqrt{\epsilon_1 - j60\sigma_1\lambda}} + 1}. \tag{4}$$

[4] A. H. Waite, "Ice Depth Soundings with Ultra-High Frequency Radio Waves in the Arctic and Antarctic and some Observed Over-Ice Altimeter Errors," USASRDL Tech. Rept. 2092; December, 1959.

Where R_c = the reflection coefficient, the subscripts v and h refer to vertical and horizontal polarization, respectively, ϕ = the phase lag in degrees between the incident and reflected waves, and σ is the conductivity of the medium.

Because of the low conductivity of snow and ice, the imaginary portion of (4) becomes negligible in all phases of this discussion. The real portion is given by

$$|R_c| = \frac{\dfrac{\sqrt{\epsilon_2}}{\sqrt{\epsilon_1}} - 1}{\dfrac{\sqrt{\epsilon_2}}{\sqrt{\epsilon_1}} + 1} = \frac{\sqrt{\epsilon_2} - \sqrt{\epsilon_1}}{\sqrt{\epsilon_2} + \sqrt{\epsilon_1}}. \tag{5}$$

The high dielectric constant and conductivity of sea water make its reflection coefficient equal to unity at 440 Mc.

The portion of the incident wave reflected from the surface of the new medium is

$$S_S = -10 \text{ Log } |R_c|^2 \text{ db.} \tag{6}$$

The loss suffered by the incident wave penetrating a new medium is expressed by

$$S_{LP} = -10 \text{ Log } (1 - |R_c|^2) \text{ db.} \tag{7}$$

Reflection coefficients for several interfaces have been calculated and are given below with the penetration and reflection losses at 440 Mc.

Interface	R_c	S_{LP} (db)	S_S (db)
Air/Ice	0.303	0.42	10.4
Air/Rock (low loss)	0.372	0.64	8.6
Air/Rock (high loss)	0.518	1.34	5.8
Air/Snow	0.111	0.04	19.1
Air/Sea Water	1.0	∞	0
Air/Fresh Water	0.80	4.4	2.0
Ice/Rock (low loss)	0.093	0.04	20.6
Ice/Rock (high loss)	0.256	0.30	11.8
Snow/Ice	0.198	0.17	14.6
Snow/Rock (low loss)	0.284	0.38	10.9
Snow/Rock (high loss)	0.434	0.9	7.3
Ice/Sea Water	1.00	∞	0
Ice/Fresh Water	0.653	2.4	3.7

Dielectric constants and conductivities of the materials involved in determining the reflection coefficients needed in this study are listed in the following table:

Medium	*Dielectric Constant*	*Conductivity (mho-meters)*
Air	1	0
Snow	1.56	10^{-5}
Ice	3.5	10^{-4}
Rock (low loss)	5.0	1×10^{-3}
Rock (high loss)	10.0	2×10^{-3}
Fresh Water	80.0	5×10^{-3}
Sea Water	80.0	4

Although values for different types of rock vary, we consider $\epsilon = 10$ representative of terrain having the worst possible dielectric characteristics. The use of this value results in a reflection coefficient for Greenland ice/rock interface of 25.6 per cent, which results in a reflection loss of 11.8 db. When snow ($\epsilon = 1.56$) rests against rock, the snow/rock reflection coefficient becomes 43 per cent and the reflection loss drops to 7.3 db.

One consideration relative to the ice/rock interface at the bottom concerns the possibility that heat caused by the tremendous pressure of hundreds of meters of continental ice or by the friction from its motion might produce a film of water between ice and rock. If this water existed, it could be expected to cause abrupt reflections when its depth approached an appreciable fraction of a wavelength.

Physical tables[5] and results of glaciological findings in both the Arctic and Antarctic[6] show that the pressure at the bottom of 3000 m of ice is 270 kg/cm² (3980 psi). This pressure could cause melt at a temperature of −2.5°C, but in both polar areas the temperatures are many degrees lower than this; *e.g.*, Byrd Station (Antarctica) gives −28.25 to −28.46°C as the gradient in the upper 300 m. If this gradient were to continue to the bottom, the temperature there could be expected to be 28 degrees below the melting point attributable to the pressure. In addition, motion of continental ice masses, according to several glaciologists, is so slow that the heat generated at the ice/rock interface is probably insignificant.[6] More will be known on this subject when 7000-ft drillings have reached bottom in Greenland next year. Recent reports indicate no traces of water beneath glaciers in the Antarctic, though there is melt water on the surface during the summer season.[7]

Altimeter Correction Factors

When a radio wave penetrates a medium other than air, the velocity of wave propagation is decreased by a factor $1/n$, where n = the index of refraction which is defined as $\sqrt{\epsilon}$. The indicators of altimeters are calibrated for use in air so that their readings will be higher when the instruments are used over denser ice or snow. To correct indicator readings, we apply:

For Ice

$$\frac{1}{\sqrt{3.5}} \times \text{Reading} = 0.535 \times \text{Reading}. \qquad (8)$$

For Snow

$$\frac{1}{\sqrt{1.56}} \times \text{Reading} = 0.800 \times \text{Reading}. \qquad (9)$$

In the discussion below, we give a typical computation for an aircraft flying 700 ft above 500 ft of ice that overlays 420 ft of rock above sea level (Fig. 4, Position 3). Calculations are based on the Signal Corps Radar Altimeter, SCR-718, which has a peak power output of 7 w, a frequency of 440 Mc, a receiver sensitivity of 5 μv, and an antenna circuit input impedance of 50 ohms. The dielectric constant (ϵ) for the ice = 3.5 and the loss tangent (tan δ) = 0.001. We assume that no scattering exists, that there is no suspended morainal debris, and that the ice temperature averages −10°C. The first reflection is obtained from the air/ice interface, the radar altimeter indicating 700 ft of surface clearance at the same time that the plane's barometric altimeter records 1620 ft above sea level. The losses suffered by the radar signal are:

The free-space attenuation for 700 ft (214 m) = 15 + 20 log 2×214 = 67.6 db, and the reflection loss at the air/ice boundary = 10.4 db. Total loss = 78.0 db; thus, the returned signal after deduction of the loss = 2360 μv.

Losses incurred in producing the second pip from the ice/rock interface are:

The free-space attenuation for 700 ft of air and 500 ft of ice = 15 + 20 Log (2×500 + 2×700)/3.28 = 73 db; attenuation in the ice = 0.075×(2×500)/3.28 = 23 db; penetration through the air/ice interface boundary = 2×0.42 = 0.84 db; and reflection loss at ice/rock boundary = 11.8 db. The total loss = 108.6 db, permitting a returned signal of 71 μv.

Results

The following comments apply only to SCR-718, 440-Mc pulsed radar altimeters, unless otherwise stated, and concern only those aircraft that fly over ice more than 120 ft thick at comparatively low altitudes. (High-flying intercontinental planes are largely exempt since most of these are equipped with higher-frequency equipment than those reported herein.)

1) These radar altimeters give no surface indication over thick ice or snow when the plane is closer than 250 ft to the surface.
2) They sometimes fail to show a bottom indication over thick sea-borne ice (200–800 ft). Low-flying pilots in such situations could have no visible pips showing, and thus be completely unwarned of ice directly beneath their wheels in periods of poor visibility.
3) Although they register normally when the plane flies over rock, land, or water, they fail to give a surface indication when the flight proceeds to a point within 250 ft over the surface of an ice slope. In such a case, if the ice is less than 1000 ft thick, the surface pip disappears and is replaced with a pip that indicates the bottom. This pip will be higher than the previously visible surface pip. Obviously, such behavior could bring fatal results under conditions of poor visibility.
4) They show no pip at all in a plane flying at an altitude of less than 250 ft over ice that is more than 1200 ft thick. If such a plane is overtaken by a snow cloud or other cause of poor visibility, it could easily crash into a rise if level flight were to be maintained.

[5] M. E. Dorsey, "Properties of Ordinary Water-Substance," Reinhold Publ. Corp., New York, N. Y., p. 603 (Table 267, "Melting Points of the Ice Unde. Hydrostatic Pressure"); 1940.

[6] H. Roethlisberger, Contract Scientist, U. S. Army Snow-Ice-Permafrost Res. Establishment, Corps of Engineers, Wilmette Ill. Correspondence concerning densities of ice and temperatures at different levels in Arctic and Antarctic regions; December 22, 1960.

[7] "Glacial History of McMurdo Sound Region, Antarctica," IGY Bull. Natl. Acad. Sci., No. 36; June, 1960.

5) If the low-flying plane referenced in 4) above were over ice thinner than 1100 ft, its radar altimeter would show a pip at approximately twice the actual ice thickness (2060 ft for 1100 ft of ice) just as the plane's wheels were about to hit the surface. Such a situation would always be fatal in periods of fog, snow, or whiteout.
6) If a plane using this equipment flies at an altitude of less than 250 ft above the surface of ice <120 ft thick or snow <180 ft thick, only a widened and garbled zero pip appears. The danger of such a reading is obvious.

Greenland Tests, 1960

1960 Greenland results showed that altimetry at 110 Mc over snow and ice should not be attempted in the future. However, this frequency proved advantageous for depth-sounding techniques. The low frequency limit is governed only by antenna size.

Results also showed that 220- and 440-Mc waves penetrated as well as in the 1959 tests and obtained accurate depths in up to 1000 ft of ice within the 20-ft limits of readability of the scopes. This supports earlier thinking that these frequencies are unsuitable for use in over-ice altimeters. Several flights over ice known to be 800 to 1100 ft thick produced pips at 1500 to 2060 ft, but showed no indication from the surface when the aircraft was less than 250 ft above it. This condition also exists when antennas are practically on the surface. Thus, radar altimeters operating at 440 Mc or below can be considered fatally dangerous if used by low-flying pilots over thick ice.

Helicopter flights with 4300-Mc FM altimeters evidenced little if any penetration from the surface of the 1000-ft-thick Greenland icecap up to heights of 1000 ft and probably can be assumed useful to within 60-ft limits[8] over ice in summer. No measurements were made over winter ice when absence of summer melt could be expected to decrease the degree of surface reflectivity.

Acknowledgment

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[8] H. B. Wurth, "Greenland Ice Cap Tests of Electronic Altimeters," Wright Air Dev. Ctr., Dayton, Ohio, WADC Tech. Rept., 59-318; July, 1959.

Correction

B. R. Bean, author of "The Radio Refractive Index of Air," which appeared on pages 260–273 of the March, 1962, issue of Proceedings, has called the following to the attention of the *Editor*. Table I should read:

TABLE I
Dry Air Refractive Index and Dielectric Constant at 0°C and 1 Atmosphere

	Frequency of Measurement	Measured N	$(\epsilon-1)10^6$	Year
1) Barrell [4]	Optical	$287.7_6 \pm 0.0_{65}$	$575.6 \pm 0.1_3$	1951
2) Birnbaum, Kryder, and Lyons [5]	9,000 Mc		$575.8 \pm 9.3_6$	1951
3) Essen and Froome [6]	24,000 Mc	$288.2_1 \pm 0.1$	576.1 ± 0.2	1951
Mean Value of $(\epsilon-1)10_3$			$575.7_5 \pm 0.1_0$	
Mean Value of N*		$288.0_4 \pm 0.0_5$		

* Derived from $n=\sqrt{\mu\epsilon}$ where $\mu-1=0.4\times10^{-6}$ is taken for radio frequencies to account for the permeability.

Correspondence

Alignment Characteristics of a Helium-Neon Optical Maser*

Minneapolis-Honeywell has constructed a continuous optical maser using helium and neon as the active medium. The device is similar to the ones reported by Herriott,[1] and Luck, Paananen and Statz.[2] The optical maser is being used in experiments to evaluate its possible applications to space guidance and communications.

The optical maser, successfully operated in 1961, is constructed as shown in Fig. 1. A photograph of the device appears in Fig. 2. The design provides a cavity for the ten to one helium-neon mixture with adjustable interferometer mirrors at each end.

All cavity seals are made with 0.010-inch diameter gold wire; copper shear seals are used in the gas handling system.

The mirrors at either end are positioned by a kinematic support consisting of a set of three micrometers coupled to the mirror by bellows. The mechanical gain of the micrometers gives an angle change of 66 seconds per 0.001 inch of micrometer travel. One of the mirrors is provided with a fine micrometer adjustment consisting of another set of three micrometers, each driving its own "coarse" micrometer by means of a lever arm. The mechanical gain from the fine micrometer to mirror angle is 0.135 second of angle per 0.001 inch of fine micrometer displacement. The fine micrometer adjustment provides a convenient way of trimming the mirror alignment after initial alignment with an autocollimator.

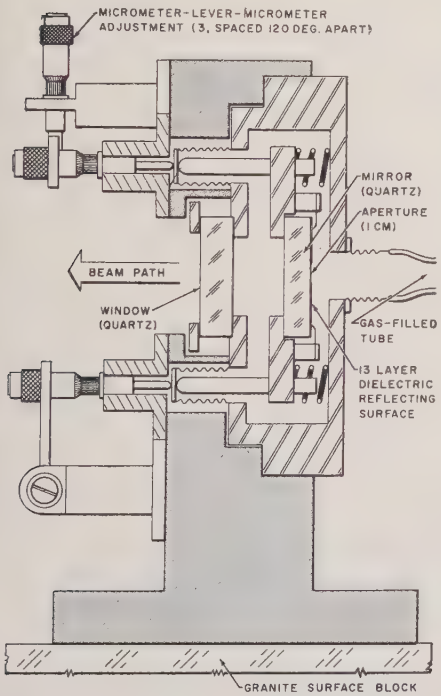

Fig. 1—Structural details of the helium-neon optical maser. (Both ends are identical except for fine micrometers on one end.)

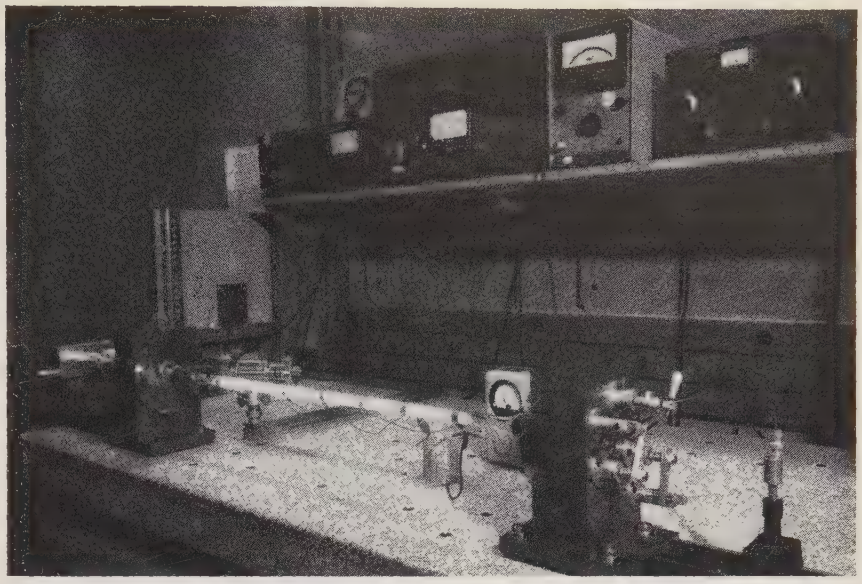

Fig. 2—Helium-neon optical maser showing end housings and alignment micrometers.

Alignment stability is provided by the 3 ft by 6 ft by 1 ft, 3000-lb granite base to which the end housings of the device are attached. The granite base is mounted on three rubber pads which rest on the base frame. Shear vibration isolation is provided at each leg of the base frame by a 2-inch stack of paper sheets.

Utilization of the granite base contributes significantly to the alignment stability. The device has been found to function for many hours after mirror alignment without additional adjustment. Thermal effects undoubtedly enter into alignment stability; no attempt has been made to temperature stabilize the environment.

The mirrors are made from 1/70 wave homosil quartz flats fabricated by E and W Optics and coated with a thirteen-layer dielectric by Dr. Francis Turner of Bausch and Lomb.

Spectral lines have been found at 1.15 and 1.16 microns. The intensity of the line at 1.16 microns is an order of magnitude or more below the 1.15 micron line.

The optical maser is pumped by a 28-Mc transmitter coupled to band electrodes on the tube; power inputs up to 70 watts can be attained.

A motor drive was coupled to one fine micrometer to make a series of runs of output vs mirror alignment. The output of the maser is monitored by a DuMont K1630 photomultiplier tube and recorded along with micrometer position to give curves as shown in Fig. 3 for various values of RF drive input. RF power input is measured by a Thruline Model 43 wattmeter. It is seen from the figure that the base of the output curve becomes increasingly narrow at low values of drive. At 5.5 watts RF drive the mirror alignment tolerance is ± 0.35 second, while at 20 watts input the tolerance is ± 1.4 seconds, about four times larger.

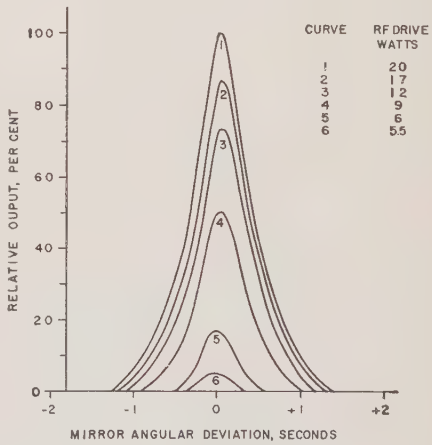

Fig. 3—Maser output vs mirror alignment for various levels of RF pumping power.

The stability of the output is a direct function of the alignment stability of the mirrors. Drift stability of ± 10 per cent over a period of 16 hours has been observed after initial warm up, which indicates a mirror stability of ± 0.1 sec.

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* Received March 12, 1962.

[1] D. R. Herriott, "Optical properties of a continuous helium-neon optical maser," *J. Optical Soc. of Amer.*, vol. 52, pp. 31–37; January, 1962.

[2] C. F. Luck, R. A. Paananen, and H. Statz, "Design of a helium-neon gaseous optical maser," Proc. IRE (*Correspondence*), vol. 49, pp. 1954–1955; December, 1961.

Ultrasonic Feedback Modulation of an Optical Maser Oscillator*

The insertion of an ultrasonic cell between the reflecting end plates of a ruby optical maser has resulted in modulation of the optical feedback in the Fabry-Perot cavity. The ultrasonic feedback modulation was found to synchronize the usually random output pulses with the ultrasonic frequency. In addition, simultaneous increase in pulse heights and a decrease in pulse widths were observed.

It is well known that light is diffracted by ultrasonic waves[1-4] in a manner similar to that experienced with an optical grating. This phenomenon arises from the alternating compressions and rarefactions altering the density of the medium through which the ultrasonic waves pass. The optical index of refraction in turn depends on the density of the medium through which the light is passing. In this manner the light is diffracted at angles θ, given by

$$\text{Sin } \theta = \frac{\eta\lambda}{\lambda^*} \tag{1}$$

where

$\eta = \pm 1, \pm 2, \pm 3, \pm 4, \cdots$
λ = light wavelength
λ^* = ultrasonic wavelength.

This applies to a light beam whose width is considerably greater than the ultrasonic wavelength. When the light beam is smaller than the sound wavelength, diffraction no longer prevails. In the latter case, the light beam in passing through the ultrasonic field is refracted back and forth in a sinusoidal manner. The deflection is given by the expression:[3,4]

$$\text{Sin } \theta = \frac{2\pi\mu L}{\lambda^*} \cos 2\pi f^* t \tag{2}$$

where

f^* = ultrasonic frequency
μ = maximum change of index of refraction caused by the sound
L = distance the light travels in the sound field.

It has often been reported in the literature that the ruby laser oscillations take place primarily within a small filamentary area whose cross section is a few tenths mm^2. It was then reasoned that if an ultrasonic cell is inserted between the ruby and an external mirror, laser action would take place when $\theta = 0$ and with a pulse repetition frequency of $2f^*$.

A two inch long, zero-degree oriented ruby was operated with an external mirror and the output pulses were recorded [see Fig. 1(a)]. The pumping energy was 3360 joules, the scope sweep rate at 5 microsec per division, scope gain of 0.1 volt per cm, and scope trigger delay of 0.7 millisec. An ultrasonic cell containing an alcohol medium was inserted between the ruby rod and the external mirror. The cell was excited at 122 kc with less than 10 watts applied to the transducer. The ruby was then optically pumped and the output pulses recorded [see Fig. 1(c)]. The pumping energy, sweep rate, scope gain, and scope trigger delay were identical to that used to obtain the results shown in Fig. 1(a).

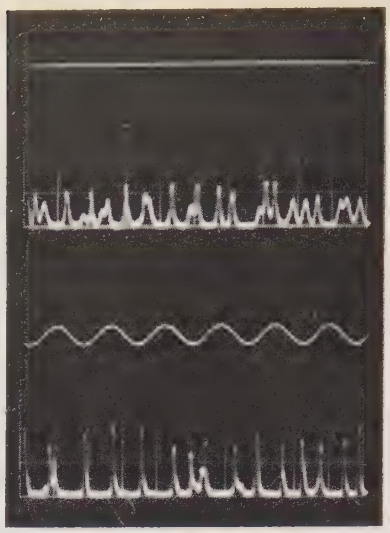

Fig. 1—Control of a ruby optical maser's oscillation by an ultrasonic cell containing an alochol medium. (a) Ruby stimulated emission with the ultrasonic off. (b) Ultrasonic waveforms at 122 kc. (c) Ruby stimulated emission with the ultrasonic on.
Time scale: 5 μsec/division. Pumping intensity: 3360 joules.

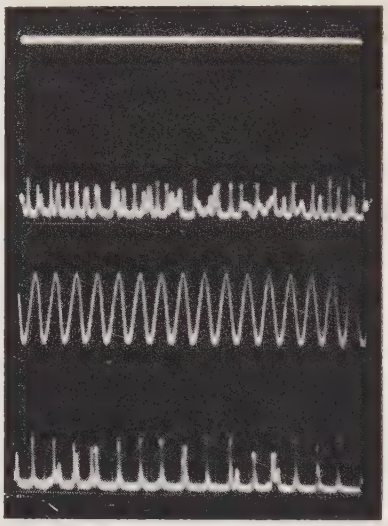

Fig. 2—Control of a ruby optical maser's oscillation by an ultrasonic cell containing a kerosene medium. (a) Ruby stimulated emission with the ultrasonic off. (b) Ultrasonic waveform at 150 kc. (c) Ruby stimulated emission with the ultrasonic on.
Time scale: 10 μsec/division. Pumping intensity: 3525 joules.

Fig. 1(c) shows a change in the output pulses in that the pulses are higher, narrower, and more evenly spaced. The laser pulses occur at approximately the maximum and minimum of the ultrasonic field intensities as predicated by (2).

Similar results were obtained at 158 kc utilizing a kerosene medium for the ultrasonic energy (see Fig. 2). The occurrence of the optical maser pulse repetition frequency at the ultrasonic frequency can be explained by the higher absorption of the kerosene medium at 6943 Å, thereby resulting in a higher firing threshold for the ruby optical maser. It is believed that the few remaining random pulses can be eliminated with the application of higher ultrasonic power.

A more detailed account of the techniques developed and the results of further experiments regarding the application of ultrasonic energy for the control of optical maser outputs will be submitted for publication at a later date.

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Transcontinental Satellite Television Transmission*

Television pictures were communicated over a transcontinental satellite relay circuit during the week of April 22, 1962. This first communications satellite television transmission was accomplished by employing very powerful and sensitive microwave radio equipment to reflect signals from coast to coast via the orbiting Echo balloon.[1] Extremely narrow transmitting and receiving radio beams (2.0 milliradians) tracked the echo satellite as it passed rapidly over the United States at an altitude of some 1000 miles.

These initial television pictures are of a limited quality since the received signals are very weak compared to the electrical noise background, against which they must be viewed (see Fig. 1), and they have been received only intermittently because they fade rapidly and deeply. The generally low signal strength and fading is caused primarily by the present deformed shape of the NASA-orbited Echo satellite. When used initially in the transcontinental voice and facsimile experiments conducted by the California Institute of Technology's Jet Propulsion Laboratory and the Bell Telephone Laboratories some two years ago[2] the satellite exhibited a near-perfect spherical shape. With the passage of time, however, the balloon has partially deflated and its surface has become wrinkled. It now appears at microwaves to be, on the average, somewhat less than half its original size, and its rough surface characteristics now cause a rapid and intense scintillation in signals reflected from it.

The facilities used for these tests were developed for Project West Ford, a U. S. Air Force supported space communications experiment. The transmitting terminal is

* Received March 6, 1962.
[1] R. Lucas and P. Biquard, "Propriet's optiques des milieux solides et liquides soumix aux vibrations élastiques ultrasonores," *J. Phys. et le Radium*, vol. 3, pp. 464–477; October, 1932.
[2] C. V. Raman and N. S. Nath, "The diffraction of light by high frequency sound waves: Part I," *Proc. Indian Acad. Sci.*, vol. A2, pp. 406–412; October, 1935.
[3] R. Lucas, "Sur les phenomenes de mirage optique dus aux ondes élastiques," *Compt. rend. Acad. Sci., Paris*, vol. 199, p. 1107; November, 1934.
[4] L. E. Hargrove, J. L. Zankel, and E. A. Hiedemann, "Effects of a progressive ultrasonic wave on a light beam of arbitrary width," *J. Acoust. Soc. Am.*, vol. 31, pp. 1366–1371; October, 1959.

* Received May 7, 1962.
[1] J. R. Pierce and R. Kompfner, "Transoceanic communication by means of satellites," Proc. IRE, vol. 47, pp. 372–380; March, 1959.
[2] W. C. Jakes, Jr., "Participation of Bell Telephone Laboratories in Project Echo and experimental results," *Bell Sys. Tech. J.*, vol. XL, pp. 975–1028; July, 1961.

Fig. 1.

located at a Lincoln Laboratory experimental field station at Camp Parks, near San Francisco, Calif. It radiates a 20-kw signal from a 60-ft diameter parabolic antenna at a frequency of 8350 Mcps. The receiving terminal is at the Lincoln Laboratory Millstone Hill field station located in the town of Westford, near Boston, Mass., where the signals were received by another 60-ft antenna and amplified in a receiver preceded by a maser pre-amplifier. With the circuit parameters used a signal-to-noise ratio of some 10 db can be expected and approximately this value has been observed.

Improvements now being incorporated into the basic radio frequency equipment will increase this carrier-to-noise ratio by about an order of magnitude within the next few months. When employed with a more sophisticated modulation/detection method, and the 135-ft rigid sphere, Echo II, expected to be launched into orbit by the National Aeronautics and Space Administration later this year, this equipment could be expected to transmit pictures approaching standard quality.

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R. V. Locke, Jr.
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† Operated with support from the U. S. Army, Navy and Air Force.

Low-Noise Reactance Amplification Using Refrigerated Epitaxial Silicon Varactor Diodes*

Recent results[1] have indicated that under some circumstances the excess noise temperature of parametric amplifiers using diffused silicon varactors can be substantially reduced by refrigeration. However, it was noted that for some diffused silicon varactors little improvement or even degradation in noise figure results with cooling.

* Received March 2, 1962.

[1] J. H. Forster, M. Uenohara, "Diffused silicon mesa diodes for use in refrigerated parametric amplifiers," Proc. IRE (*Correspondence*), pp. 82–83; January, 1962.

The present paper reports a similar investigation carried out for diffused epitaxial silicon diodes. Here it was found that an improvement in double channel noise figure resulted for all the epitaxial units with refrigeration.

The diffused epitaxial varactor diode structure is indicated in Fig. 1. The substrate is heavily doped N^+ silicon to minimize series resistance, the epitaxial film is lightly doped N type, a few microns in thickness, and the p-n junction is formed by diffusion of acceptors from a high surface concentration. The net impurity profile has been chosen to minimize series resistance for a specified breakdown voltage (between 10 and 20 v), provide a reasonable capacitance swing, and is such that the device resistance should either improve or at least remain constant at temperatures down to about 100°K.

The junction depth and film thickness permit reduction of the mesa height to about 10 microns, provided suitable contacting techniques are used.

When compared to the diffused silicon mesa varactor diode structure previously used to investigate the temperature dependence of the noise figure[1] for a refrigerated silicon varactor diode, the epitaxial structure is superior. For a given mesa diameter or junction capacitance, an epitaxial diode has a cutoff frequency (defined at zero bias) up to 80 per cent higher for essentially the same capacitance-voltage characteristic. This improvement results largely from reduction of series losses, and is in general reflected in improved room-temperature noise figure, particularly for junction capacity in the 0.5- to 2.5-pf range.

The measurement of excess noise temperature has been carried out by inserting the diodes into a parametric amplifier using degenerate operation with the pump frefrequency at 11.7 Gc and the signal and idler frequency at 5.85 Gc. The gain of the amplifier was kept at 16 db by optimal tuning and adjustment of pump power for the required gain.

The noise figure was measured by inserting 3 db of attenuation between the amplifier and receiver and then compensating for the lost noise power by admitting into the amplifier the noise power of a gas discharge lamp (T_L) attenuated by a factor L. The noise figure was then calculated by using the relation

$$F = \frac{1}{L}\left(\frac{T_L}{290} - 1\right) + \frac{1}{G},$$

where G = gain of the amplifier.

To refrigerate the diodes liquid nitrogen was used in two ways. One method used heat conduction in a silver rod, the other used a hollow diode holder into which a controlled stream of nitrogen was blown through a nozzle. The temperature was measured by an AuCo-Cu thermocouple at the wafer side of the diode.

Fig. 2 is a plot of the measured excess noise temperature as a function of the diode temperature.

In general the excess noise temperature is lowered by 50°K when the diode is cooled to 100°K, although there is a leveling of noise temperature for diode EP4, 19 and 21. This behavior was apparently associated with the diode encapsulation used, since the leveling of excess noise temperature was not observed for diodes EP121 and 123, which were fabricated in an improved package.

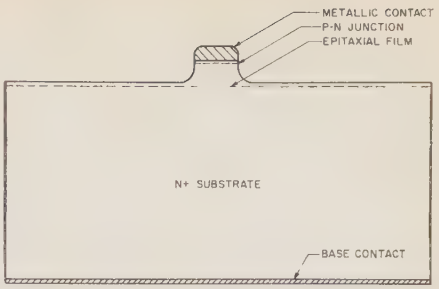

Fig. 1.

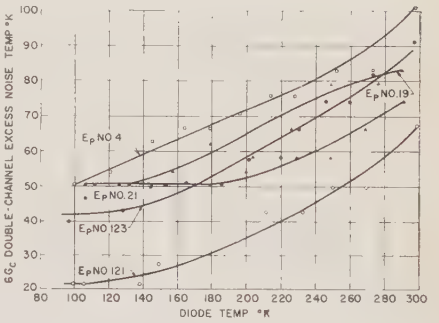

Fig. 2—Si epitaxial diodes.

From these experiments one may conclude that the silicon epitaxial diodes are about equal in performance to GaAs point contact diodes,[2] with added ruggedness, reliability, and power capability.

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[2] M. Uenohara and W. M. Sharpless, "An extremely low noise 6-kMc parametric amplifier using gallium arsenide point-contact diodes," Proc. IRE, vol. 47, p. 21A; December, 1959.

Reversed-Biased *P-N* Junctions in Electron Tubes*

Reversed biased p-n junctions are in wide use as detectors of nuclear radiations. The authors have also demonstrated that p-n junctions can be used to detect single charged positive ions of low kinetic energy in a mass spectrometer.[1] By accelerating the secondary electrons produced via positive ion impact and focusing these electrons onto a p-n junction, it was shown that the junction functions as a high-gain current amplifier for mass spectrometer ion currents in the range 10^{-12}–10^{-18} a. There appear to be many other potential applications for reverse-biased junctions, however, if these

* Received February 19, 1962. This work was done for the United States Atomic Energy Commission under Contract No. W-31-109 Eng. 52.

[1] F. A. White, J. C. Sheffield, and J. W. Mayer, "Silicon junctions detect positive ions," *Electronics*, vol. 34, p. 74; January, 1961.

are suitably incorporated as an element in a vacuum tube.

"Semitron" is the name given to a suggested new class of electronic components that combine electron tubes and semiconductors in order to utilize certain characteristics of each in a single device. Consider the triode arrangement of Fig. 1 in which the cathode is operated at a high negative potential and the usual plate is replaced by an *n-p* junction. Each electron arriving at the "plate" will generate electron-hole pairs in the space-charge region of the junction, provided that the impinging electrons have kinetic energies sufficient to penetrate the junction "dead layer." Using silicon it is possible to obtain charge multiplication of 1000 electron-hole pairs for 3.5-kev electrons, discounting the kinetic energy lost in the "dead layer." In an experimental semitron, 12-kev primary electrons of 1.0×10^{-9} a have given output junction currents of 1.4×10^{-6} a; 24-kev electrons of 7.5×10^{-11} a have produced 3.0×10^{-7} a, the current amplification varying linearly between these two cathode potentials.

It would appear that the design of practical semitron tubes is feasible on the basis of two important considerations. First, even low energy electrons have an appreciable range in silicon (~1.75 microns/10 kev)[2] *i.e.*, sufficient to convert a large fraction of the kinetic energy of primary electrons into electron-hole pairs. Secondly, basic materials for making *p-n* junction "plates" have low vapor pressures and could probably be sealed in static vacuum tubes without serious "outgassing" problems.

In principle it would also seem desirable to consider the design of not only low-current amplifiers, but oscillators or multiswitching devices as illustrated in Fig. 2. Photo-diodes could also be engineered to have the same amplification as 5- or 6-stage electron multipliers, all the amplification being achieved in a single step. The exceedingly fast rise time of the junctions, isolation of the low-voltage plate circuit from the grid, and wide choice of junctions materials and impedance characteristics, make the semitron a candidate for specialized applications as detectors and circuit components.

Disadvantages and limitations of such semitron tubes include their restriction to low currents and the need for high cathode-plate potentials.

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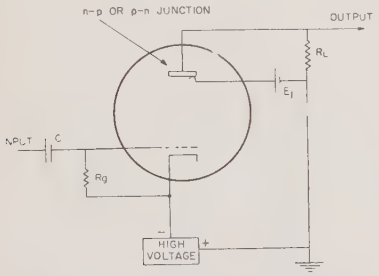

Fig. 1—Schematic diagram of "semitron" amplifier utilizing *p-n* junction as plate in electron tube.

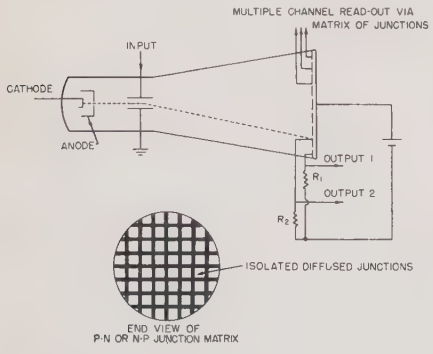

Fig. 2—Schematic diagram of a multiple channel read-out system employing a matrix of *p-n* junctions in a cathode-ray tube.

Flux Analysis of a Transistor Structure*

In two recent papers[1,2] the "flux analysis" of added carrier transport problems in semiconductors has been discussed in some detail. It is the purpose of the present note to apply these methods to the analysis of a one-dimensional transistor structure. The object here is not the derivation of new results, but a demonstration of the elementary nature of this approach, which is nevertheless capable of deriving the Ebers and Moll large signal relations and expressions for the saturation currents and the dc alphas simultaneously. The notation is identical with that of the papers referred to above.

Consider the transistor structure of Fig. 1. (A *p-n-p* structure is used for illustration.) The fluxes crossing the junctions 1 and 2 and those in the base region (of width W) will be denoted by subscripts 1, 2 and W, respectively. Voltages V_1, V_2 are those applied to the two junctions by the external bias circuits. We assume a uniform rate of thermal flux generation dA in the base, at the plane x, so that

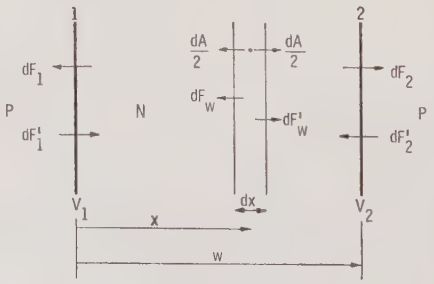

Fig. 1.

$$\frac{dA}{dx} = \frac{p_n}{\tau_p},$$

as before, where p_n = hole concentration and τ_p = hole lifetime, in the base region.[1,2] We then have the flux equations

$$\begin{aligned} dF_W &= \frac{dA}{2} + R(W-x)dF_W' + T(W-x)dF_2' \\ dF_W' &= \frac{dA}{2} + R(x)dF_W + T(x)dF_1' \\ dF_1 &= T(x)dF_W + R(x)dF_1' \\ dF_2 &= T(W-x)dF_W' + R(W-x)dF_2' \end{aligned} \quad (1)$$

where R and T are the bulk reflection and transmission coefficients defined by McKelvey, Longini and Brody. We will assume, as in the single junction case[2]

$$dF_1' = Be^{qV_1/kT}; \quad dF_2' = Ce^{qV_2/kT}, \quad (2)$$

where B, C are constants to be determined. Eq. (2) will be recognized as the Shockley (low level) boundary conditions. For high level operation, other boundary conditions could be used.

Solving (1) simultaneously, we find the determinant of the system to be

$$\Delta = 1 - R(x)R(W-x), \quad (3)$$

and solving for the net fluxes crossing the two junctions, we get

$$\begin{aligned} dF_1 - dF_1' &= dF_1'\left(\frac{\xi_1}{\Delta} - 1\right) + \frac{dA}{2\Delta}\eta_1 + T(W)dF_2' \\ dF_2 - dF_2' &= dF_2'\left(\frac{\xi_2}{\Delta} - 1\right) + \frac{dA}{2\Delta}\eta_2 + T(W)dF_1', \end{aligned} \quad (4)$$

where

$$\begin{aligned} \xi_1 &= R(x)\Delta + R(W-x)T^2(x) \\ \xi_2 &= R(W-x)\Delta + R(x)T^2(W-x) \\ \eta_1 &= T(x)[1 + R(W-x)] \\ \eta_2 &= T(W-x)[1 + R(x)], \end{aligned}$$

and the identity

$$\frac{T(x)T(W-x)}{\Delta} = T(W)$$

has been used.[3]

To determine the constants B and C, we set $V_1 = V_2 = 0$ in (2), and substitute in (4), putting the net fluxes crossing the junctions equal to zero. We then get for the net fluxes, using

$$\left(1 - \frac{\xi_1}{\Delta}\right) \equiv \chi_1; \quad \left(1 - \frac{\xi_2}{\Delta}\right) \equiv \chi_2; \quad T = T(W),$$

and, arranging terms,

$$\begin{aligned} dF_1 - dF_1' = \frac{dA}{2\Delta(\chi_1\chi_2 - T^2)} \\ \cdot[\chi_1(\chi_2\eta_1 + T\eta_2)(1 - e^{qV_1/kT}) \\ - T(\chi_1\eta_2 + T\eta_1)(1 - e^{qV_2/kT})] \end{aligned} \quad (5)$$

with a similar expression for $dF_2 - dF_2'$.

If we compare (5) with the expression

* Received February 14, 1962; revised manuscript received February 23, 1962.

[1] J. P. McKelvey, R. L. Longini, and T. P. Brody, "Alternative approach to the solution of added carrier transport problems in semiconductors," *Phys. Rev.*, vol. 123, pp. 51–57; July 1, 1961.

[2] J. P. McKelvey, "Analysis of semiconductor *p-n* junctions and junction devices by a flux method," *J. Appl. Phys.*, to be published.

[2] C. Feldman, "Range of 1–10 kev electrons in solids," *Phys. Rev.*, vol. 117, pp. 455–459; January, 1960.

[3] J. P. McKelvey, R. L. Longini, and T. P. Brody, *op. cit.*, see (13).

derived by Ebers and Moll[4] [their (16)],

$$I_E = -\frac{I_{E_0}}{1-\alpha_N\alpha_I}\left(e^{qV_1/kT}-1\right) + \frac{\alpha_I I_C}{1-\alpha_N\alpha_I}\left(e^{qV_2/kT}-1\right),$$

we can identify the corresponding terms, and hence get

$$I_{E_0} \to \frac{dA}{2\Delta}\left(\eta_1 + T\frac{\eta_2}{\chi_2}\right)$$

$$I_{C_0} \to \frac{dA}{2\Delta}\left(\eta_2 + T\frac{\eta_1}{\chi_1}\right)$$

$$\alpha_N \to \frac{T}{\chi_1}; \qquad \alpha_I \to \frac{T}{\chi_2}. \tag{6}$$

It must be borne in mind that the flux expressions correspond to the case of differential thermal flux generation at the plane x, and the full expressions will be obtained only when the differential expression (5) is integrated across the base region.

As a first approximation, we make use of the fact that for the usual transistor geometry $\lambda \ll W \ll L$. (λ = mean free path, L = diffusion length of carrier.) Since the arguments of the sinh and cosh functions entering the expressions for the transmission and reflection coefficients T and R are of the order $W/L \ll 1$ (see McKelvey, Longini and Brody for explicit expressions for T and R), we may put $\sinh W/L \simeq W/L$, $\cosh W/L \simeq 1+W^2/2L^2$. Then, replacing x by $W/2$ everywhere and expanding the expressions with some care we obtain, in this approximation

$$\frac{1}{\alpha_N} = \frac{1}{\alpha_I} = 1 + \frac{3W^2}{4L^2}. \tag{7}$$

To obtain I_{Eo} and I_{co}, we note that

$$dI_{Eo} = \frac{dA}{2\Delta}\left(\eta_1 + \alpha_I\eta_2\right)$$

$$dI_{Co} = \frac{dA}{2\Delta}\left(\eta_2 + \alpha_N\eta_1\right),$$

and the thermal flux generation function dA, when integrated across the base, gives $A = (p_n/\tau_p)W$. We then find, from (6) in this approximation

$$I_{Eo} = I_{Co} \simeq \frac{p_n W}{2\tau_p}\left[\frac{2T(1+R)}{1-R^2}\right] \simeq \frac{p_n W}{\tau_p}\frac{T}{1-R},$$

which yields

$$I_{Eo} = I_{Co} \simeq \frac{p_n W}{\tau_p}\left(\frac{1}{1+\lambda W/3L^2}\right),$$

which is very nearly $= p_n W/\tau_p$. We then find

$$1 - \alpha_N\alpha_I \simeq \frac{3W^2}{2L^2},$$

and finally

$$I_E \simeq -\frac{2p_n D}{3W}\left(e^{qV_1/kT}-1\right) + \left(1-\frac{3W^2}{4L^2}\right)\frac{2p_n D}{3W}\left(e^{qV_2/kT}-1\right),$$

where we have used $L^2 = D\tau$. A similar expression holds for I_c. The junction currents of course can be evaluated more accurately by integrating across the base.

The effects of surface recombination, emitter efficiency and space charge recombination and generation can in principle be included in the flux formulation, and it also appears possible to extend the flux method to the analysis of more complex structures, such as the four-layer switch. It is hoped to deal with these extensions of the flux analysis in a subsequent publication.

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[4] J. Ebers and L. Moll, "Large-signal behavior of junction transistors," Proc. IRE, vol. 42, pp. 1761–1772; December, 1954.

Photomultiplier Detection of Microwave Modulated Light*

A recent communication[1] described the principles of dynamic crossed-field electron multiplication (DCFEM) and its successful use in the detection of light modulated at intermediate frequencies. This letter reports a subsequent experiment in which this method was used in a photomultiplier which directly detects light modulated at microwave frequencies. By driving the photomultiplier at a frequency f, which is close to the light modulation frequency f_s, the heterodyne detection is realized by observing the photomultiplier output current which is modulated at the difference frequency $f_d = |f - f_s|$.

The modulated light is achieved by driving a Kerr-cell shutter[2] with 1.25-μsec RF pulses at a repetition frequency of 450 pps. The light is modulated over a frequency range variable from 2.995 Gc to 3.005 Gc. A LF mechanical shutter is also placed in the path of the light beam to provide a "zero light" reference.

The DCFEM detector is driven continuously at a frequency at 3.000 Gc with the output connected to an oscilloscope. No phase locking is provided between the two microwave generators driving the Kerr cell and the detector, respectively.

Fig. 1(a) is the oscilloscope trace when the difference frequency f_d is nearly zero. Due to frequency drift of the generators, the phase at which the photoelectrons are sampled within the multiplier causes both positive and negative pulse outputs to appear. The "zero light" reference is the upper trace. Due to lead capacitance, the bandwidth of the output circuit of the multiplier was approximately 200 kc, resulting in rise-time distortion of the pulses.

For the trace shown in Fig. 1(b), the conditions were identical to those of Fig. 1(a) except that the light modulation frequency was changed to give a difference frequency of approximately 1 Mc.

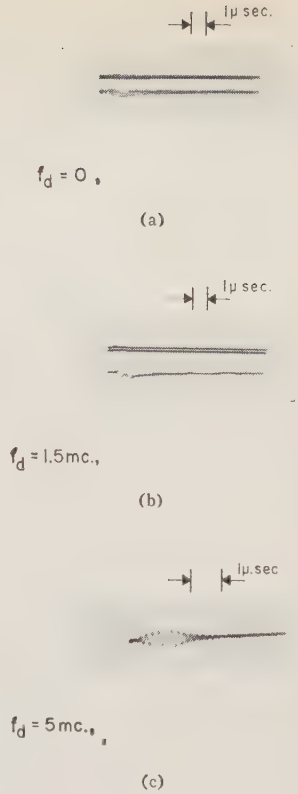

Fig. 1.

The trace of Fig. 1(c) is obtained with the mechanical shutter omitted and with an inductor connected across the output of the multiplier to resonate with the lead capacitance at the difference frequency which in this case is approximately 5 Mc.

From the traces of Fig. 1(a) and 1(b), the depth of modulation of the light may be calculated and is found to be approximately 0.4. Since this value agrees well with the depth of light modulation measured by optical interference methods,[2] it can be concluded that the method of electron multiplication as well as the Cesium-Antimonide photocathode is capable of microwave frequency response. In addition, this method of detection offers sensitivity and SNR comparable to that of conventional electrostatic photomultipliers at lower frequencies. The photocathode current in this experiment was less than 10^{-2} μa while the output current was between 10 and 100 μa.

For completeness it should be mentioned that in another experiment with the same photomultiplier, a different procedure was used in the preparation of the photocathode resulting in a different spectral response and quantum efficiency. In this experiment, no response to microwave modulated light was observed, thus again raising the question as to whether all photocathodes under all conditions are capable of responding to microwave modulated light.[3]

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* Received February 28, 1962.

[1] O. L. Gaddy and D. F. Holshouser, "High gain dynamic microwave photomultiplier," Proc. IRE, vol. 50, pp. 207–208; February 1962.

[2] D. F. Holshouser, H. Von Foerster and G. L. Clark "Microwave modulation of light using the Kerr effect," *Proc. Opt. Soc. Am.*, vol. 51, pp. 1360–1365; December, 1961.

[3] D. F. Holshouser, "The Time Element in Photoelectric Emission," Ph.D. thesis, University of Illinois, Urbana; 1958.

A Resonance Technique for Nondestructive Read-Out of Thin Magnetic Films*

This note describes a technique which utilizes UHF ferromagnetic resonance to obtain nondestructive read-out in thin magnetic films. It is well known that thin permalloy films prepared by vacuum evaporation in the presence of a magnetic field exhibit a uniaxial anisotropy.[1] A film of this type exists as a single domain with the magnetization M directed along the axis of anisotropy. The Larmor precession frequency of the magnetization vector depends upon the magnetic field internal to the specimen. In the absence of any external field, an internal field arises from the anisotropy field H_k and the demagnetizing field $4\pi M$. The magnetization vector will precess in the presence of this internal field at a frequency f_k which is given by the relation[2]

$$f_k = \gamma(4\pi M H_k)^{1/2}, \tag{1}$$

where γ is the gyromagnetic ratio. This frequency is of the order of 600 Mc. If a small external field is applied parallel to the anisotropy axis, the Larmor precession frequency will either increase or decrease depending upon whether the field is parallel or antiparallel to the magnetization vector. If the field is kept below H_c, the critical value that causes the magnetization to switch, the precession frequency as a function of applied field is given by the relation

$$f_0 = f_k(1 \pm H/H_k)^{1/2}. \tag{2}$$

The plus sign corresponds to the parallel case and the minus sign to the antiparallel case. This asymmetry provides the possibility of a method for sensing the direction of the magnetization vector of a magnetic film. The basic memory element can be constructed as shown in Fig. 1. The film is

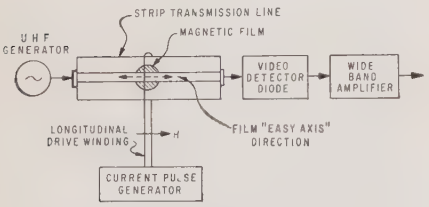

Fig. 1—Circuit for nondestructive sensing of magnetic film.

placed under a strip transmission line which is driven by a UHF generator and is terminated by a video detector diode. The anisotropy axis of the film is perpendicular to the transverse UHF magnetic field and parallel to the interrogation field, H, which is applied by means of an orthogonal winding. A transmission line section loaded with a magnetic film in this manner exhibits an attenuation constant, α, which is a function of the

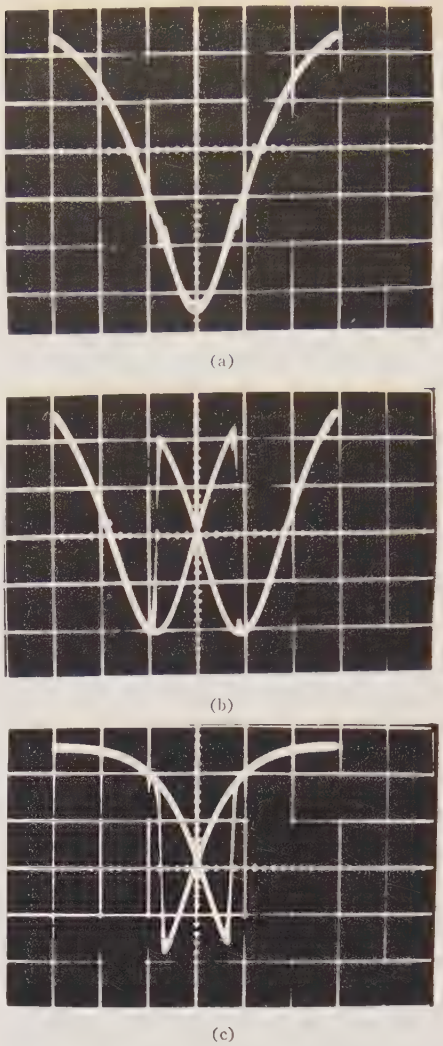

Fig. 2—Detector output voltage vs longitudinal magnetic field for a single 0.140-in permalloy film. Vertical scale: 1.25 mv/cm. Horizontal scale: 2.3 oe/cm. (a) $f=f_k=680$ Mc. (b) $f=780$ Mc. (c) $f=570$ Mc.

longitudinal field. The exact solution for α is not yet available; however, a good approximation results when it is taken to be proportional to $\sqrt{\mu_2}$, where μ_2 is the imaginary component of the complex permeability of the film. For this approximation, the voltage out of the video diode is given by the following expression

$$V = V_0 - \frac{\text{Constant}}{\left\{[1 \pm h + (f/f_k)^2]^2 + (\Delta H/2H_k)^2\right\}^{1/2}}, \tag{3}$$

where ΔH is the width of the resonance line and h is H/H_k. The relative detector output vs the applied field for a single 0.140-in. diameter permalloy dot in a 35-ohm strip transmission line is shown in Fig. 2. The longitudinal field is a 60-cps sinusoid applied by means of a pair of Helmholtz coils.

Fig. 2(a) shows the case for $f=f_k$. The maximum absorption occurs for $H=0$. Fig. 2(b) is the case $f=1.2\,f_k$. The maximum absorption occurs at $(1+h)^{1/2}=1.2$. Fig. 2(c) is the case $f=0.8\,f_k$. The maximum absorption occurs at $(1-h)^{1/2}=0.8$. In all of the above cases, the magnetization vector switches at $H=H_c$. Nondestructive read-out can be accomplished by applying a unipolar longitudinal field of magnitude $H<H_c$ while driving the transmission line at a frequency either above or below f_k. For $f>f_k$, α increases when M is parallel to the pulse field and decreases when M is antiparallel to the pulse. The opposite effect will take place when $f<f_k$.

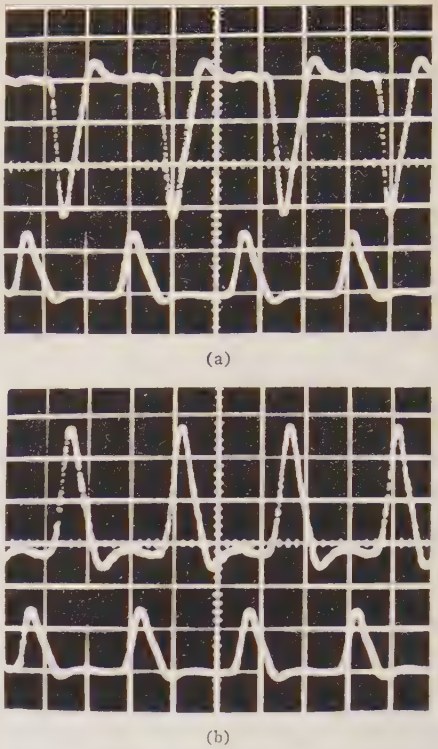

Fig. 3—Top trace in both cases is the amplified output of detector for $f=780$ Mc. Vertical scale: 20 mv/cm. Horizontal scale: 50 nsec/cm. Bottom traces represent the word current. Vertical scale: 50 ma/cm. Horizontal scale: 50 nsec/cm. (a) H parallel to M. (b) H antiparallel to M.

An experimental 7×5 word organized memory plane has been built to test this NDRO technique. A strip-line resistive power splitter was used to distribute UHF power to the transmission (digit) lines which were terminated with video detector diodes in wide-band mounts. Write-in was accomplished by means of a permanent magnet. Typical amplified read-out pulses are shown in Fig. 3 for an interrogation pulse of $H=0.8\ H_c$. The interrogation pulses are 30 nsec wide and were applied at a repetition rate of 7 Mc. The unamplified pulse outputs of the detector are typically 2 to 6 mv with 5 to 15 mw of RF driving power and with interrogation pulses as narrow as 7 nsec. Films have been interrogated at a 5 Mc repetition rate for several hours with no detectable degradation of the read-out pulse shape. In order to investigate the characteristics of a long digit line, a strip-line section 2 ft long loaded with 80–140 mil dots was tested. At least a 1.5 mv read-out signal was observed for each film in the line with 15 mw of UHF power. This NDRO technique with its potentially low access time and good read-out SNR should be adaptable to medium sized, semipermanent storage-type memories.

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* Received March 12, 1962.

[1] M. S. Blois, Jr., "Preparation of thin magnetic films and their properties," *J. Appl. Phys.*, vol. 26 pp. 975–980; August, 1955.

[2] D. O. Smith, "Static and dynamic behaviour of thin permalloy films," *J. Appl. Phys.*, vol. 29, pp. 264–273; March, 1958.

Broadband Hybrid-Coupled Tunnel-Diode Amplifier in the UHF Region*

Hybrid-coupled tunnel-diode amplifiers have been reported previously in the literature;[1,2] however, performance capabilities of such an amplifier, taking into consideration the parasitic circuit elements of the tunnel diode, have not been presented.

A block diagram of the hybrid-coupled tunnel-diode amplifier is shown in Fig. 1. Each amplifier module consists of a tunnel diode with circuit elements shown in Fig. 2. If a hybrid employing coupled transmission lines of length $n\lambda/4$ is employed where n is an odd integer, the gain of the hybrid-coupled tunnel-diode amplifier is as follows:[3]

$$G = 10 \log_{10} |2S_{12}S_{14}| + 10 \log |\Gamma|^2, \quad (1)$$

where G = amplifier gain in db, S_{12} and S_{14} are scattering coefficients of the hybrid and Γ = voltage reflection coefficient of the tunnel diode network. The effect of the first term has been previously discussed.[3] If the frequency sensitivity of the hybrid is neglected, the first term in (1) does not contribute to the gain and it can then be shown that[4]

$$G = 10 \log_{10} |\Gamma|^2 = 10 \log_{10} \cdot \left\{ \frac{[\beta^2 - 1 - n + \theta]^2 + \beta^2 \left[\gamma + \frac{n}{\gamma} - \frac{\theta}{\gamma}\right]^2}{[\beta^2 - 1 - n + \theta]^2 + \beta^2 \left[\gamma - \frac{n}{\gamma} - \frac{\theta}{\gamma}\right]^2} \right\}, \quad (2)$$

where

$$\omega_0^2 = \frac{1}{LC} \qquad \eta = \frac{Z_0}{|-R|} \qquad Z^2 = \frac{L}{C}$$

$$\beta^2 = \left(\frac{\omega}{\omega_0}\right)^2 \qquad \gamma = \frac{Z}{R} \qquad \theta = \frac{R_s}{|-R|},$$

where Z_0 = characteristic impedance of hybrid. L_d, C, R_s and $-R$ are circuit elements of the tunnel diode (Fig. 2). $L = L_p + L_d$ where L_p is the inductance of the shorted length of line used in the amplifier and serves to peak the gain.

The apparent noise figure of the hybrid-coupled tunnel-diode amplifier is as follows:

$$F' = 1 + \frac{4}{G}\left[\frac{20 I_0 Z_0}{(1 - \eta - \theta - \beta^2)^2 + \beta^2\left(\gamma - \frac{\eta}{\gamma} - \frac{\theta}{\gamma}\right)^2}\right] + \frac{4}{G}\left[\frac{}{\left(1 + \frac{1}{\eta} - \frac{1/n}{1 + \beta^2/\gamma^2}\right)^2 + \beta^2\left(\frac{\gamma}{\eta} - \frac{1/\gamma\eta}{1 + \beta^2/\gamma^2}\right)^2}\right] + \frac{1}{G}.$$

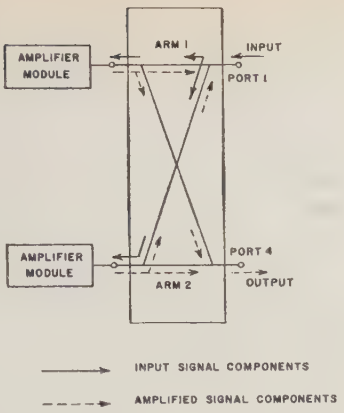

Fig. 1—Hybrid-coupled tunnel-diode amplifier.

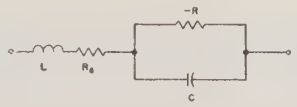

Fig. 2—Tunnel-diode network.

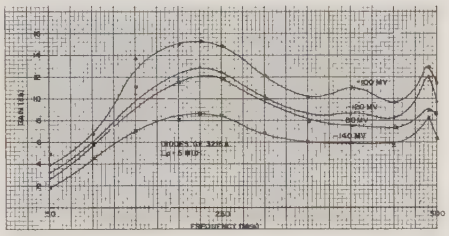

Fig. 3—Frequency response of hybrid-coupled diode amplifier.

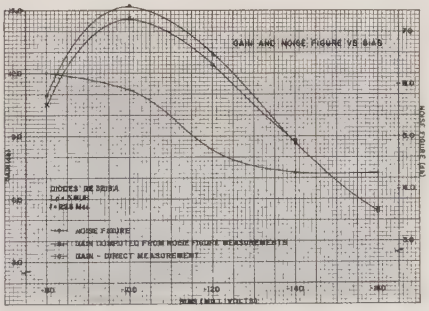

Fig. 4.

A practical hybrid-coupled tunnel-diode amplifier was developed using a commercially procured hybrid and a pair of Type 3218A tunnel diodes. Measured data of gain vs frequency for different levels of bias are shown in Fig. 3. Measured data for gain and noise figure at a given frequency (225 mcs) vs different values of bias are shown in Fig. 4.

A stability analysis of the amplifier module has been previously reported.[5]

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* Received January 4, 1962. This work was performed for the Rome Air Development Center under Contract No. AF 30(602)2184.

[1] J. Sie, "Absolutely stable hybrid coupled tunnel diode amplifier," Proc. IRE, vol. 48, p. 1321; July, 1960.

[2] J. C. Greene, "Noise considerations for hybrid coupled negative-resistance amplifiers," Proc. IRE, vol. 49, pp. 626–627; March, 1961.

[3] R. M. Kurzrok, "Bandwidth of Hybrid Coupled Tunnel Diode Amplifier," Proc. IRE, vol. 50, pp. 226–227; February, 1962.

[4] D. Fleri and H. Boyet, "Investigation of Traveling Wave Parametric and Hybrid Couped Tunnel Diode Amplifiers," TN RADC-TR-61-231, under AF Contract No. AF 30(602)2184, p. 31; July, 1961.

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A Metal-Base Transistor*

The realization of relatively long mean free paths for hot electrons in metals[1–5] has suggested the use of metals for the base region of transistors. Mead[6] suggested using a tunnel emitter, a metal base, and insulating barrier layers for emitter and collector. Spratt, Schwarz, and Kane[7] have reported experimental results on a similar device using a germanium surface barrier collector, although it appears that in practice their device may be a metal interface amplifier instead.

The purpose of this communication is to point out that tunnel emission is not required, nor is necessarily desirable, for a metal-base transistor. A superior device can be constructed which uses ordinary thermionic emission rather than tunneling.

Aside from practical considerations the thermionic emitter can be shown to be superior to the tunnel emitter on the basis of frequency response. For example, consider the expression for the maximum frequency of oscillation f_{max},[8]

$$f_{max} = \frac{1}{4\pi}\left(\frac{\omega_\alpha}{r_b C_c}\right)^{1/2} \quad (1)$$

where r_b is the base resistance, C_c is the collector capacitance, and ω_α is the radian alpha cutoff frequency, which can be expressed in the following approximate form:

$$\omega_\alpha = \frac{1}{R_e C_e + \tau_{ec}} \quad (2)$$

where R_e is the emitter resistance, C_e is the

* Received March 19, 1962.

[1] W. C. Walker, N. Wainfau, and G. L. Weissler, "Photoelectric yields in the vacuum ultraviolet," *J. Appl. Phys.*, vol. 26, pp. 1366–1371; November, 1955.

[2] H. Thomas, "The outer photoelectric effect of the alkali metals. I. The dependence on layer thickness for potassium of the range of photoelectrons in the metal," *Z. Phys.*, vol. 147, pp. 395–418; January, 1957.

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[8] D. F. Page, "A design basis for junction transistor oscillator circuits," Proc. IRE, vol. 46, pp. 1271–1281; June, 1958.

emitter capacitance, and τ_{ec} is the emitter-to-collector transit time. By using a metal base region, the base resistance and the emitter-to-collector transit time can both be reduced by about an order of magnitude each, thus increasing f_{max} by about one order of magnitude. If the tunnel emitter is used, however, both R_e and C_e are increased, thus tending to reduce ω_α and f_{max}. If a conventional metal-semiconductor surface barrier is used for the emitter, however, R_e and C_e are comparable in magnitude to the values for conventional p-n-p and n-p-n structures, thus enabling f_{max} to be increased to the fullest possible extent.

With these considerations in mind, a Ge-Cu-Ge structure has been tested. The copper was electroplated onto n-type germanium having a resistivity of 2 ohm-cm, thus forming a large-area collector barrier. The blunt corner of a second n-type germanium crystal with the same resistivity was then brought to bear against the thin Cu film to serve as an emitter. Accurate measurements of copper film thickness were not carried out. However, it was qualitatively observed that α decreased as the Cu film was made thicker.

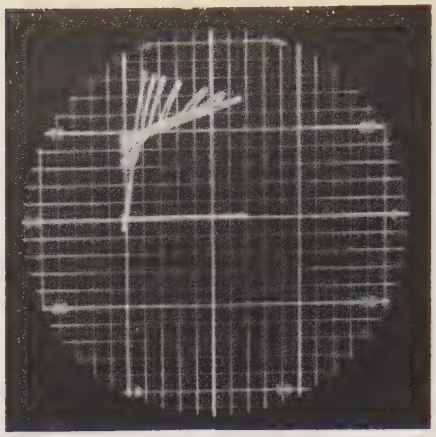
The units were tested by displaying the output and transfer characteristics on a dynamic transistor curve tracer. The grounded-base and grounded-emitter characteristics were both observed. The results of these tests can be summarized as follows:

1) Essentially zero alpha was obtained when the units were first tested at low emitter currents.
2) As the emitter current was increased, a value would be reached at which α would rapidly increase and reach an equilibrium value in about 5 sec.
3) Alpha was still low at low emitter currents and rose to a maximum at about 20-ma emitter current.
4) The collector back current slowly increased during testing at high currents.

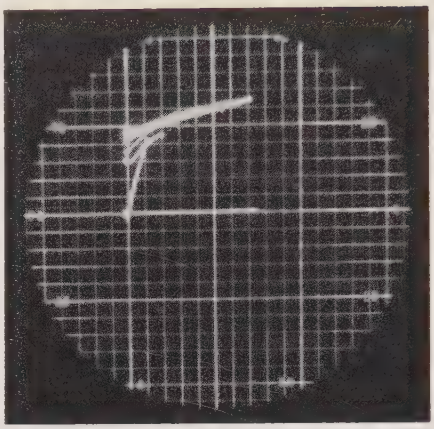
One possible interpretation of this behavior is as follows. The low α at low emitter currents could be caused principally by a low emitter injection efficiency. At sufficiently high values of emitter-base bias, the hole current saturates while the useful electron current continues to increase, thus increasing the emitter injection efficiency. The rapid increase with time of alpha at high emitter currents could be caused by a reduction in the height of the collector barrier. This could be brought about by diffusion of Cu into the collector Ge crystal occasioned by localized heating.

Fig. 1 shows typical grounded-emitter characteristics obtained . The large emitter-base bias required is clearly evident in these curves. The maximum value of β reached on this particular unit was about 2. Values as high as 3 were obtained on some units, a typical value being 2.5. The base resistance on these units was quite low, typically being on the order of 1 to 10 ohms. The low collector resistance (reached after high emitter currents were drawn) is also apparent in these curves.

These characteristics are of course inferior to those of conventional transistors.



(a)



(b)

Fig. 1—Grounded-emitter characteristics. (For both curves, $\Delta I_b = 5$ ma, with 5 ma/hor 12 div. and 4 v/vert. div.) (a) Output characteristics, I_c vs V_{ce}. (b) Transfer characteristics, I_c vs V_{be}.

However, they do appear to demonstrate the principles of a metal-base transistor. It would appear from the recent work by Spitzer[9] that Cu is not the best metal to use for the base. According to Spitzer's photoexcitation measurements, the mean free path of 0.952 volt electrons in Cu is only about 145 Angstrom units. Gold would appear to be a better choice, having a measured mean free path of about 700 Angstrom units. The use of Au should therefore yield higher values of base transport factor and therefore higher values of α and β. The use of Ge for the emitter is likewise not necessarily the best choice. A larger band-gap material like Si would probably give a higher emitter injection efficiency at low values of emitter current. Finally, a large-area emitter should be used in order to avoid the large spreading resistance of a small-area contact. With these improvements, the metal-base transistor could possibly compete with conventional p-n-p and n-p-n structures, particularly at the higher frequencies where the metal-base structure has potential advantages.

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[9] W. G. Spitzer, "Electron Attenuation Length in Metals," presented at the Symp. on Hot Electrons in Thin Films, Philco Corp. Sci. Lab., Blue Bell, Pa.; February 28, 1962.

8-Inch Ruby Amplifier*

This note reports on a novel device for exciting a ruby LASER amplifier. The device, utilizing the elliptical principle, operates on a minimum amount of excitation energy and achieves expected gains.

Amplification of a factor of eight has been obtained at room temperature in a ruby LASER, using a ruby 8 inches long by $\frac{5}{8}$ inch in diameter. The end faces of the ruby were uncoated and the reflectivity was calculated to be 8 per cent. The interesting feature of the experiment was the device used to excite a ruby rod of the stated size. A pumping scheme was desired which was reasonably efficient and did not require a prohibitive amount of input energy. Helical flash lamps, although effective for smaller rods, did not appear to satisfy the requirements. A design utilizing two elliptical cavities with a mutual focal line (as shown in Fig. 1) was selected for its merits and was constructed.

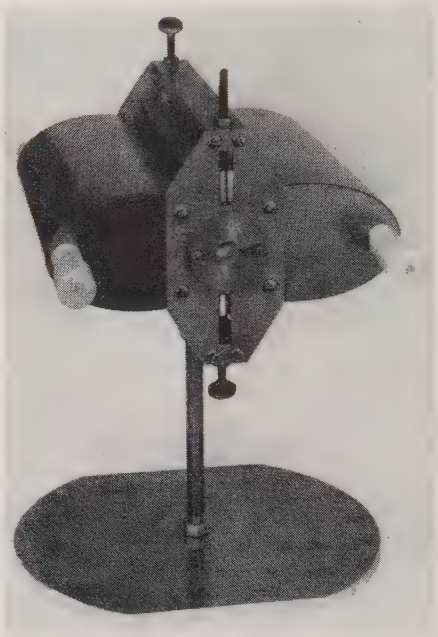


Fig. 1—Dual elliptical cavity.

In this cavity, the ruby LASER rod was positioned at the mutual focal line and the excitation sources are placed at the remaining two focal lines. The excitation sources used were two straight xenon flash lamps, 8 inches in length, capable of operating at a 6000-Joule input. The lamps are $\frac{5}{8}$ inch in diameter to match them to the ruby amplifier crystal. The dual elliptical cavity is constructed of highly polished brass sheet formed over two elliptical end plates. The interior of the cavity is mirrored with a vacuum-deposited aluminum coating.

A schematic of the amplifier laboratory setup is shown in Fig. 2. The oscillator consists of a 2-inch ruby rod housed in a single elliptical cylinder and is excited by a 3-inch straight xenon flash lamp rated at 1000-

* Received April 6, 1962.

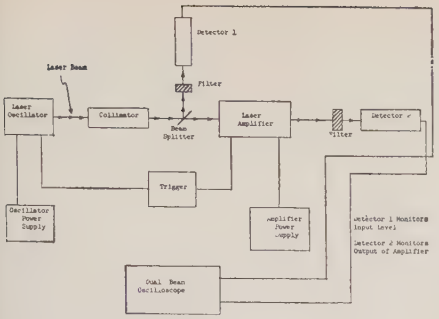
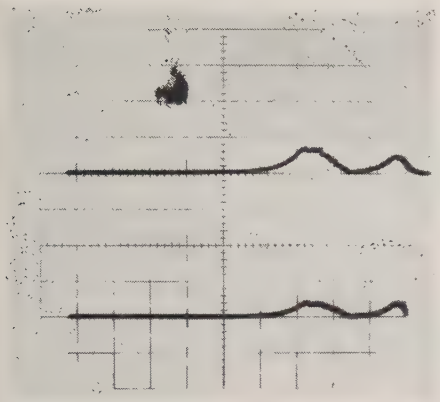
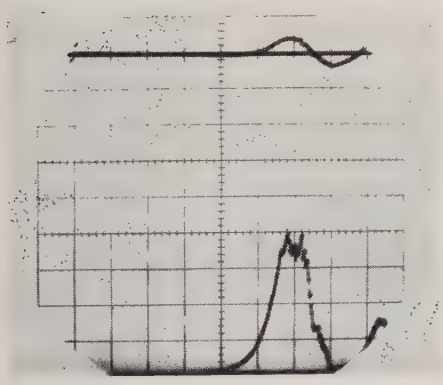


Fig. 2—Laboratory setup.



(a)



(b)

Fig. 3—Detector outputs. (a) Detector outputs with no amplification, amplifier ruby out of system. (b) Detector outputs with amplification, amplifier ruby in system. (Same oscilloscope sensitivity for all measurements.)

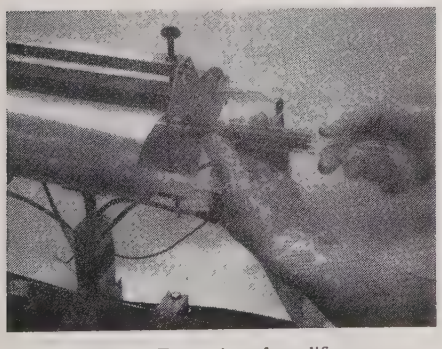


Fig. 4—Front view of amplifier.

Joule maximum input. It is constructed in the same manner as the amplifier cavity.

Fig. 3 is a photograph of two oscilloscope screen images showing two photo-detector outputs, with and without amplification. The upper trace in each oscilloscope screen image shows the input level to the amplifier. The lower trace is the amplifier output. The amplifier ruby was removed from the system when the upper set of traces were recorded. Comparison of the two screen images shows a net gain of eight with amplifier excitation. For this amplification a total of 4600 Joules was applied to the amplifier system, and 300 Joules was applied to the oscillator system. No measurements have yet been made of the energy output from either system, nor of the threshold energy for oscillation in the amplifier ruby. Also, no significant fluorescence was detected emanating from the amplifier crystal which was not caused by the input signal. Theoretical considerations of end-face reflectivity of the ruby rod show that the maximum possible gain, neglecting lattice and diffraction loses, with flat ends is 10.6. At this value of gain the amplifier should break into self-oscillation, because the 92 per cent loss on reflection will be regained by the 8 per cent of the beam internally reflected.

Fig. 4 shows a front view of the amplifier with the 8-inch ruby exposed. The ruby is housed in a glass tube to facilitate cooling to liquid nitrogen temperatures for future tests.

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The Aperture-to-Medium Coupling Loss in Beyond-Horizon Propagation*

Recent correspondence[1] suggested a curve based upon experimental data for evaluating coupling loss when narrow-beam antennas are used in tropospheric propagation beyond the horizon. Unfortunately, the datum point at $\theta/\alpha=6.3$ in the table and figure of that correspondence (from which much of the curve is derived) has been given incorrectly.

Fig. 1 of the present letter shows the same measured coupling losses plotted in the same co-ordinates used by Yeh,[1] the ordinate being the coupling loss for two antennas of beamwidth α in a beyond-horizon path of scatter angle θ. Most of these data are plotted as solid dots, the exception being the point showing 11-db loss at $\theta/\alpha=6.3$ which is a square. This point[2] is the coupling loss for one narrow-beam antenna rather than two, as was implied by Yeh.[1]

* Received March 5, 1962.

[1] L. P. Yeh, "Experimental aperture medium coupling loss," Proc. IRE (*Correspondence*), vol. 50, p. 205; February, 1962.

[2] A. B. Crawford, D. C. Hogg, and W. H. Kummer, "Studies in tropospheric propagation beyond the horizon," *Bell Sys. Tech. J.*, vol. 38, p. 1067–1178; September, 1959.

The procedure of doubling the coupling loss of one antenna to obtain the loss when two are used is open to question. However, following Yeh,[1] if we make the dubious assumption that the coupling loss using two narrow-beam antennas is twice that obtained using one, the appropriate point to plot at $\theta/\alpha=6.3$ on Fig. 1 is 22 rather than 11 db; this point is indicated by a cross.[3]

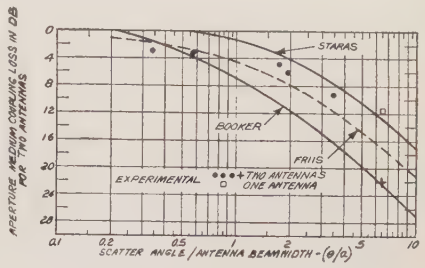

Fig. 1—Aperture to medium coupling loss.

The figure shows the theoretical curves due to Staras, and Booker and de Bettencourt, as given by Yeh.[1] Also shown (as a dashed line) is a curve derived from the reflection theory of Friis, *et al.*,[4] good agreement with the experimental values is evident, especially for low values of θ/α.

The dependence of the coupling loss on path length and frequency is not fully understood. For example, one would not necessarily expect the coupling loss of 30-ft antennas operating at 8 kMc on a 150-mile path ($\theta/\alpha\simeq5$) to be the same as that obtained using 120-ft antennas at 500 Mc on a 600-mile path ($\theta/\alpha\simeq5$). In the latter case the common volume is at a great altitude, and propagation mechanisms other than scatter (such as those observed in the Pacific region) may well predominate; one would hesitate to plot such data along with the theoretical curves of Fig. 1, which are based on rather specific concepts.

More long-term experimental data are needed to clarify the situation.

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[3] Part of this loss is due to local bending which is not aperture to medium coupling loss in the usual sense.

[4] H. T. Friis, A. B. Crawford, and D. C. Hogg, "A reflection theory for propagation beyond the horizon," *Bell Sys. Tech. J.*, vol. 36, p. 627–644; May, 1957.

Author's Reply[5]

It was unfortunate that the data given in Dr. Hogg, *et al.'s* paper was misinterpreted.[2] After Dr. Hogg's correction, the aperture-medium coupling loss for one narrow-beam antenna at $\theta/\alpha=6.3$ becomes 11 db, which seems excessive when compared with the other datum points of my suggested experimental curve at smaller θ/α ratios. This may be explained by the fact, as pointed out by Dr. Hogg,[2] that this loss includes both loss of gain and local bending effects of the 60-

[5] Received March 20, 1962.

ft antenna. The latter could be appreciable, especially for very small antenna beamwidths, such as 0.3° in the present case. Since the two effects could not be separated readily, the question of what would be the loss due to aperture medium coupling remains unsolved.

It may be true that the procedure of doubling the coupling loss of one antenna to obtain the loss when two are used is open to question. To my knowledge, it has been used by Angel, *et al.*,[6] and others. Pending the development of a better method, this procedure may be considered as a transitional measure.

The omission of the calculated curve derived from the reflection theory[4] was unintentional, but again unfortunate. I am glad that it does show good agreement with the experimental values.

The choice of θ/α as one of the coordinates to plot the experimental curve is purely a matter of convenience. Since all the theories give the aperture-medium coupling loss as a function of θ/α, it seems appropriate to use the same form for the experimental curve so that the difference between theory and data could be easily visualized.

Finally, I fully agree with Dr. Hogg that more long-term experimental data are needed to clarify the situation.

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[6] Angel, *et al.*, "Propagation measurements at 3480 Mc/s over 173-mile path," *Proc. IEE*, vol. 105, pt. B, pp. 128–142; January, 1958.

Thin Film Triode Research*

Our laboratory has for some time been investigating the problem of constructing an all-evaporated thin film triode of the type suggested by Mead.[1] The basic structure we have been aiming for is composed of an aluminum emitter, Al_2O_3 emitter barrier (20 Å), aluminum base (100 Å), collector barrier Al_2O_3 (200 Å), and an aluminum collector electrode.

One finds with such a structure that the injected current, that current which is composed of "hot" electrons from the emitter which are supposed to pass through the base region to the collector, is much smaller than can be accounted for by the elementary analysis. This analysis is one which treats the structure as a one-dimensional double potential barrier problem.

In order to find what modification should be made in the elementary picture of the conduction process of thin oxide barriers, we have made an extensive study of the temperature dependence of volt-ampere characteristics as a function of thickness of the Al_2O_3. We would like to summarize the results of these measurements at this time.

As in Figs. 1, 2, and 3 the conduction characteristics of such barriers is of the form:

$$J = Ae^{-\phi/kT}e^{\alpha(s)V}.$$

In this equation:

J = current density (amperes/cm²)
V = voltage across barrier (volts)
s = barrier oxide thickness
$\alpha(s)$ = a function of barrier thickness as shown in Fig. 4.

The energy parameter ϕ was found to be approximately 0.35 electron-volt, but decreased at lower temperatures as shown in Fig. 3. Furthermore, barriers of less than 60 Å thickness show much less temperature dependence, the ϕ at room temperature decreasing several fold from 0.35 ev. The constant A is of the order of 10^{-8} amperes/sq cm.

Our theoretical interpretation of these results is as yet incomplete, but we are considering the following alternatives:

1) We consider the apparent barrier energy, ϕ, measured from the emitter Fermi level, as representing an energy level in the cathode electrode at which the number of electrons available and the probability of penetration of the oxide barrier are maximized. This level is thus somewhere below the actual barrier height and above the Fermi level in the electrode. With this picture we have then a way of explaining why we have difficulty injecting "hot" electrons which are above the apparent barrier height of 0.35 volt. The actual barrier is in reality higher, perhaps near 2.0 ev.
2) The barrier height between Al and the Al_2O_3 is of the order of magnitude of the activation energy of 0.35 ev observed in the temperature experiment, but the inability to get successful injection of "hot" electrons is due to an increase in the barrier height from space charge buildup of electrons initially injected and then trapped in the oxide barrier.

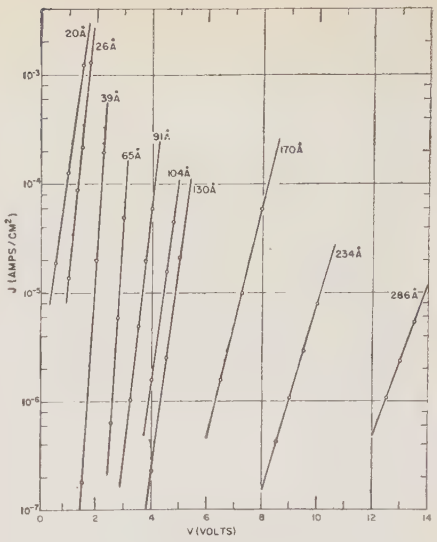

Fig. 1.

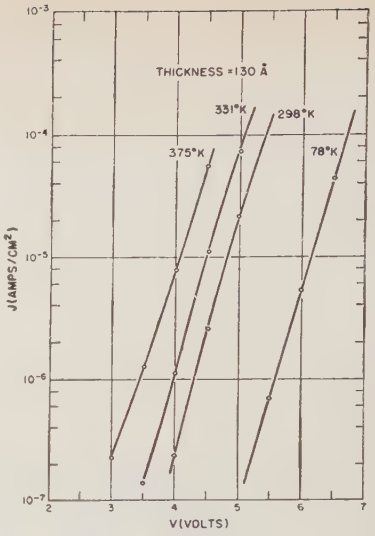

Fig. 2.

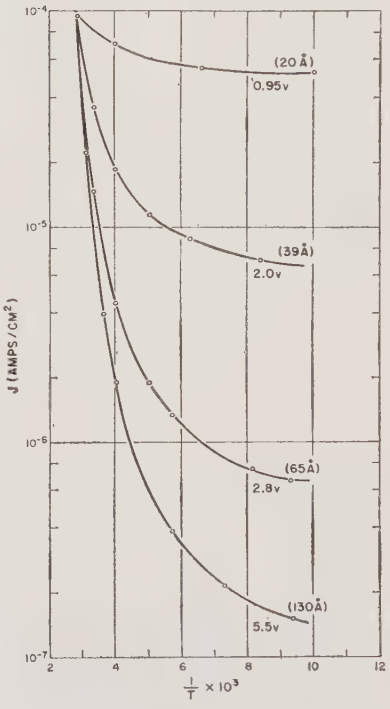

Fig. 3.

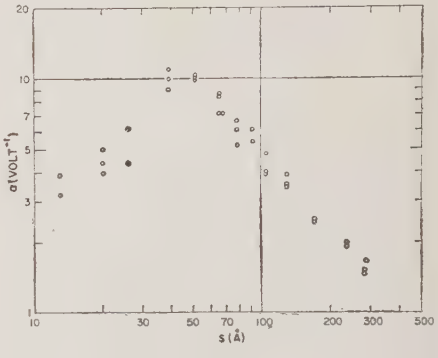

Fig. 4.

* Received March 22, 1962. This work was supported jointly by the Air Force under Contract Nos. AF-33(657)-7644 and AF-33(616)-7700, and by NASA under Research Grant NsG-234-61.

[1] C. A. Mead, "Operation of tunnel emission devices," *J. Appl. Phys.*, vol. 32, pp. 646–652; April, 1961.

We hope that these brief remarks stimulate some suggestions from individuals working along these same lines.

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Optical Maser Action in $CaWO_4:Er^{3+}$ *

The systems of trivalent rare earths in $CaWO_4$ are very suitable for maser operation; oscillations were reported previously with Nd^{3+},[1] Tm^{3+},[2] Ho^{3+} [3] and Pr^{3+} [4] in this host. The pumping takes place in the weak forbidden 4f-4f absorption lines, but the fluorescent quantum efficiency is near unity and this line pumping is sufficient to start oscillations.

We have observed maser action in the $CaWO_4:Er^{3+}$ system at liquid nitrogen temperature in the middle of the FT-524 helical xenon flash lamp with an electrical input threshold power of about eight hundred joules stored in 400 μfd.

The trivalent erbium has a partially filled 4f shell, and the ^4I is the lowest lying spin-orbit multiplet of the three hole ($4f^{11}$) system. The fluorescence spectra of $CaWO_4:Er^{3+}$ in the 1.6 micron region is shown in Fig. 1. This emission corresponds to the transition from the $^4I_{13/2}$ state to the various levels of the crystal field split $^4I_{15/2}$ ground state as shown in Fig. 2. The maser oscillation occurs at 1.612 μ (6200 cm^{-1}) in the fluorescent line marked with the arrow. The maser operates as a four level system, the terminal level being 375 cm^{-1} above the ground state.

In addition to the 1.61 μ band, the $CaWO_4:Er^{3+}$ system also has a strong green fluorescence when excited by u.v. radiation, but we have not made the system oscillate at this frequency.

The absorption spectra of $CaWO_4:Er^{3+}$ at liquid N_2 temperature is shown in Fig. 3. The various components of the ^4I multiplet show up, but the pumping takes place primarily in the set of intense absorption lines around 5200 Å to 3800 Å.

The $CaWO_4$ crystals doped with one molar per cent of Er^{3+} and charge compensated with an equal amount of lithium were grown at RCA Laboratories. The maser cavity was 1 inch in length and $\frac{1}{4}$ inch $\times \frac{1}{4}$ inch in cross section. The crystal was immersed in liquid N_2 and flashed in the center of the FT-524 helical xenon flash lamp. The output was recorded with a PbSe detector operating at room temperature with a time constant of 15 μsec. Fig. 4(a) shows the lamp output below threshold. In Fig. 4(b) the maser output slightly above threshold can be seen. The relaxation oscillations are present. Fig. 4(c) shows the output much above threshold.

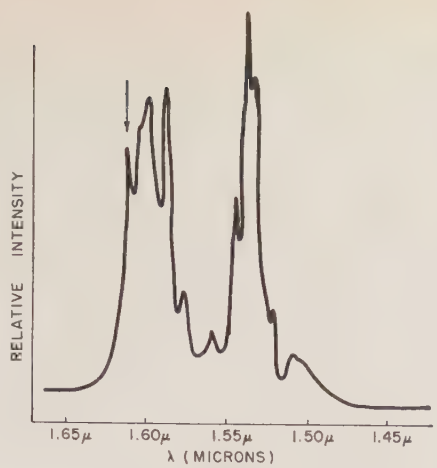

Fig. 1—Fluorescence spectra at $CaWO_4:Er^{3+}$ at 77°K. The maser line is marked with an arrow.

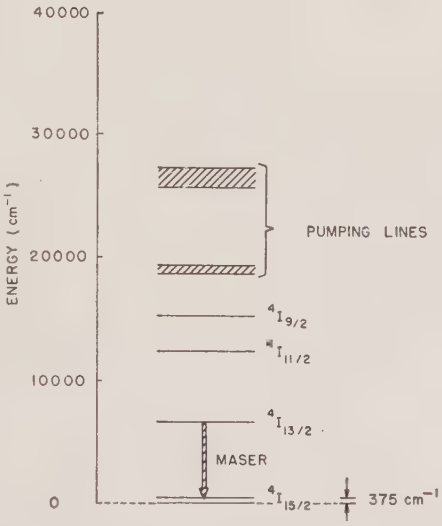

Fig. 2—Energy level diagram for $CaWO_4:Er^{3+}$ showing maser transition.

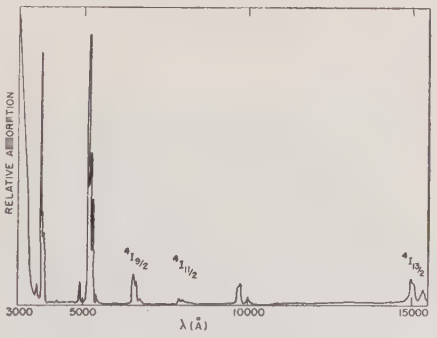

Fig. 3—Absorption spectra of $CaWO_4:Er^{3+}$ at 77°K.

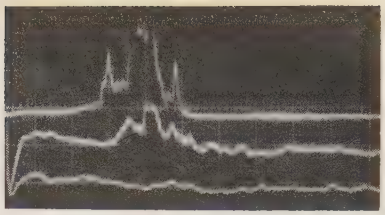

Fig. 4—Pulsed maser output from $CaWO_4:Er^{3+}$ at 1.612 μ at 77°K. Time scale: 500 μ sec/cm. (a) Bottom trace: Flash lamp output below maser threshold. Ordinate: 10 mv/cm. (b) Center trace: Maser output slightly above threshold showing relaxation oscillations. Ordinate: 10 mv/cm. (c) Top trace: Maser output about 30 per cent above threshold. Ordinate: 500 mv/cm.

To reduce the threshold power, work is continuing to optimize the crystal quality and the doping concentration. However, in light of the few pumping lines and the poor fluorescent quantum efficiency of the maser line, this material is not as suitable for continuous operation as some of the other maser systems.

The authors gratefully acknowledge the contributions of P. N. Yocom for the preparation of the materials, and M. Kestigian and P. G. Herkart for growing the $CaWO_4$ crystals. The many discussions with G. J. Goldsmith, H. R. Lewis, D. S. McClure, and J. P. Wittke were most valuable.

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Pulsed and Continuous Optical Maser Action in $CaF_2:Dy^{2+}$ *

The important requirements for four level maser materials are 1) broad absorption bands in the spectral region where high power lamps are available; 2) sharp line fluorescence with high quantum efficiency; 3) a fluorescent line that terminates on a level $\Delta\nu$ above the ground state, where $\Delta\nu > kT$; 4) there should be no strong absorption band at the frequency $\nu = 2\nu_{maser} + \Delta\nu$; if such an absorption band exists, ions in the emitting level at $\nu_{maser} + \Delta\nu$ can absorb rather than emit light at the frequency ν_{maser}.

Divalent rare earths in a suitable host can well fulfill the above requirements. Transitions of 4f electrons to the outer 5d or 6s levels provide broad absorption

* Received May 7, 1962. This work was first reported orally in a post-deadline paper at the meeting of the American Physical Society in Washington, D. C., April 25, 1962, and was partially supported by WADD, ARDC, of the U. S. Air Force.

[1] L. F. Johnson and K. Nassau, "Infrared fluorescence and stimulated emission of Nd^{3+} in $CaWO_4$," Proc. IRE (*Correspondence*), vol. 49, pp. 1704–1706; November, 1961.

[2] L. F. Johnson, G. D. Boyd, and K. Nassau, "Optical maser characteristics of Tm^{3+} in $CaWO_4$," Proc. IRE (*Correspondence*), vol. 50, pp. 86–87; January, 1962.

[3] L. F. Johnson, G. D. Boyd, and K. Nassau, "Optical maser characteristics of Ho^{3+} in $CaWO_4$," Proc. IRE (*Correspondence*), vol. 50, pp. 87–88; January, 1962.

[4] A. Yariv, S. P. S. Porto, and K. Nassau, to be published.

* Received May 7, 1962; revised May 15 and May 25, 1962. Part of this work (pulsed operation) was first reported orally in a post-deadline paper at the meeting of the American Physical Society in Washington, D. C., April 25, 1962, and was partially supported by WADD, ARDC, of the U. S. Air Force.

bands throughout the visible region with oscillator strengths of the order of 10^{-2} to 10^{-3}. The forbidden 4f-4f transitions give sharp line fluorescence. The terminal state to ground state separation $\Delta\nu$ can be achieved by two mechanisms; either making use of the crystal field splitting of the ground level, or by using a spin-orbit multiplet above the ground state.

The second four level solid-state maser announced was divalent samarium in CaF_2,[1] the only divalent rare earth maser reported so far. In this material, however, a sharp 5d-4f fluorescent transition was made to oscillate and it could only operate at temperatures below 30°K. We have succeeded in achieving maser action at 2.36 μ in divalent dysprosium doped CaF_2, where pumping takes place in the broad 4f-5d bands and the oscillation occurs in a 4f-4f transition.

The fluorescence spectra of $CaF_2:Dy^{2+}$ at liquid N_2 temperature is shown in Fig. 1. The lines correspond to transitions from the $^5I_7$ to the $^5I_8$ state,[2] (Fig. 2) and the structure is due to the crystal field splitting of the $^5I_8$ state. The other members of the ^5I multiplet were not found to emit. The strongest line (marked with an arrow) is at 2.36 μ (4235 cm^{-1}), 90 cm^{-1} above the ground state established by the transition at 2.312 μ (4325 cm^{-1}), and this is the line that breaks into maser oscillation at liquid N_2 temperature.

The absorption spectrum at the top of Fig. 2 shows the broad pumping bands throughout the whole region from 10000 Å to 3000 Å (10000 to 33000 cm^{-1}). The bands, however, only start at 10500 Å (9500 cm^{-1}), and there is no absorption at $2\nu_{maser}+\Delta\nu = 4325+4235 = 8560$ cm^{-1} to prevent maser action by absorptive transitions from the $^5I_7$ state to the 5d levels.

The crystals of CaF_2 containing 0.03 molar per cent of divalent dysprosium were grown at RCA Laboratories by the Czochralski method. The crystal was made into a maser cavity (1 inch long, $\frac{1}{4}$ inch $\times \frac{1}{8}$ inch cross section), immersed in liquid N_2 and pumped with xenon flash lamp. The output was observed with a PbSe detector operating at room temperature with a time constant of 15 μsec. Fig. 3(a) shows the lamp pulse of an FT-524 lamp. In Fig. 3(b) the output of the maser is recorded slightly above threshold. The relaxation oscillations can clearly be seen. As the crystal is pumped higher above threshold, the intensity of the maser pulse is increased, and the pulse lengthens to about 1.5 msec.

The threshold of oscillation at liquid N_2 temperature using an FX-100 lamp $\frac{7}{8}$ inch away from the crystal with no focusing occurs with about one joule of electrical input to the lamp. Under identical conditions the best available $CaWO_4:Nd^{3+}$ and $CaF_2:U^{3+}$ maser crystals both had a threshold power of about eight joules. When the $CaF_2:Dy^{2+}$ specimen is cooled to liquid He temperature, threshold input power further reduces by a factor of ten to one-tenth of a joule, and the maser output exhibits no relaxation oscillations.

The lifetime of the $^5I_7$ fluorescing level is concentration depending; the longest lifetime observed was 12 milliseconds. This long lifetime coupled with the low measured pulsed threshold power indicates that this material is especially suitable for continuous (CW) operation. We have indeed operated $CaF_2:Dy^{+}$ continuously, using an AH-6 mercury lamp as a source and two spherical mirrors with a total light-gathering aperture of f/0.25 as the focusing system. For CW operation the crystal was cooled either dynamically with flowing liquid nitrogen (cooled by pumping to about 70° K), or helium gas (about 15° K), or statically by emersion in liquid neon (27° K).

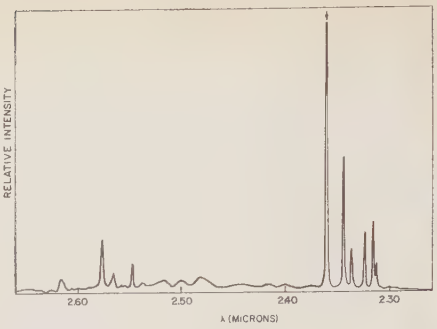

Fig. 1—The fluorescence spectra of $CaF_2:Dy^{2+}$ at liquid N_2 temperature. The frequency of the maser oscillation is marked with the arrow.

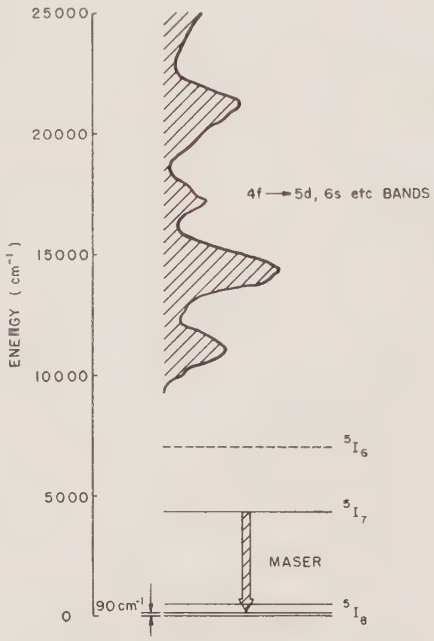

Fig. 2—The energy levels of $CaF_2:Dy^{2+}$ showing the maser transition.

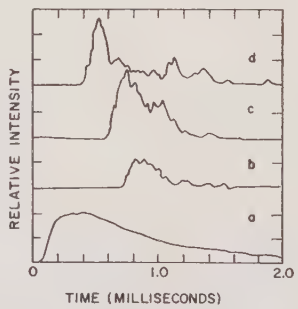

Fig. 3—(a) The relative lamp intensity as a function of time below threshold. The ordinate is 10 mv/cm. (b) The maser output with an input 2 per cent above the threshold voltage. The ordinate is 100 mv/cm. (c) The maser output with an input 4 per cent above the threshold voltage. The ordinate is 100 mv/cm. (d) The maser output with an input 15 per cent above the threshold voltage. The ordinate is 200 mv/cm.

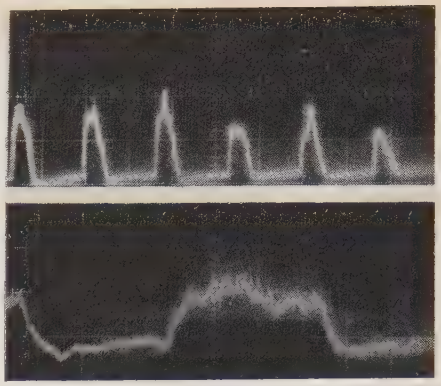

Fig. 4—Maser action in $CaF_2:Dy^{2+}$. The time scale is 5 msec/cm. Upper trace: Quasi-continuous maser action excited by ac lamp at 120 cps. Lower trace: Continuous maser action excited by dc lamp. The maser beam is mechanically chopped at 30 cps.

Fig. 4 shows the continuous operation at 27° K. The upper trace shows the 120 cps quasi-continuous operation when the AH-6 lamp is run with an ac supply. The lower trace shows the CW maser output chopped at 30 cps. The threshold condition for CW operation occurred with 600-watts electrical input power to the lamp. The measured CW output power was 2 milliwatts. With the optimization of various parameters much higher output powers are expected.

The authors gratefully acknowledge the contributions of P. N. Yocom for the preparation of the materials and M. Kestigian, P. G. Herkart, and H. E. Temple for growing the CaF_2 crystals. The many discussions with G. Goldsmith, H. R. Lewis, D. S. McClure, and J. P. Wittke were most valuable.

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Optical Maser Action in $CaF_2:Tm^{2+}$ *

Because the strong 4f-5d absorption bands are particularly good for pumping, the divalent rare earths in CaF_2 are especially suitable systems for maser operation, the sharp 4f-4f transitions providing the maser line. Maser action has already been reported with Sm^{2+} in CaF_2[1] and in SrF_2[2] by Sorokin and Stevenson and recently by us

* Received May 7, 1962. This work was partially supported by WADD, ARDC of the U. S. Air Force. Maser action in $CaF_2:Tm^{2+}$ was first reported orally in a paper on the energy level scheme of this system by Z. J. Kiss at the meeting of the American Physical Society in Washington, D. C., April 26, 1962. (*Bull. Am. Phys. Soc.*, II, vol. 7, p. 356; 1962.)

[1] P. P. Sorokin and M. J. Stevenson, *IBM J. Res. and Dev.*, vol. 5, p. 56; 1961.

[2] Z. J. Kiss, to be published.

[1] P. P. Sorokin and M. J. Stevenson, *IBM J. Res. and Dev.*, vol. 5, p. 56; 1961.

[2] P. P. Sorokin, M. J. Stevenson, J. R. Lankard, and G. D. Pettit, *Bull. Am. Phys. Soc.*, II, vol. 7, p. 195; 1962.

in $CaF_2:Dy^{2+}$.[3] We now have also observed maser action in $CaF_2:Tm^{2+}$ at liquid helium temperature at 1.116 μ.[4]

The $CaF_2:Tm^{2+}$ system has been studied extensively[5] and an energy level scheme deduced. The f^{13} $CaF_2:Tm^{2+}$ system has a strong fluorescence in the 1.1 micron region and this is shown in Fig. 1 at liquid N_2 temperature. The two strong lines at 1.116 μ and at 1.189 μ are transitions to two of the crystal field split components of the $^2F_{7/2}$ ground state. The other weak substructure is of vibrational origin.[5] This fluorescence is excited in broad 4f-5d absorption bands shown in Fig. 2 at room and liquid He temperatures. These transitions are very intense with oscillator strengths of 10^{-3}.

The energy level diagram of the $CaF_2:Tm^{2+}$ system is shown in Fig. 3.[5] The 1.116 μ fluorescent line which corresponds to a transition to the ground state is the line that breaks into oscillation as a three level maser. This is somewhat surprising since the 1.189 μ line terminates 556 cm^{-1} above ground state and could provide a suitable four level system with depopulated terminal state even at room temperature. We believe that this behavior of the system is due to absorption of the 1.189 μ radiation by transitions from the excited $^2F_{5/2}$ level to the 5d bands.

In Fig 2 the frequencies of $\nu_{^2F_{5/2}}+\nu_{maser}$ are marked for both the three level and four level maser systems. And indeed absorption of ν_4 (4 level maser) from the $^2F_{5/2}$ state falls near the peak of the 4f-5d absorption band at all temperatures, while absorption of ν_3 (3 level maser) at liquid helium temperature misses the first band and the system can break into oscillation.

The crystals of $CaF_2:Tm^{2+}$ (with dopings of 0.05 molar per cent Tm^{2+}) were grown at RCA Laboratories. The maser cavity consisted of 1 inch long crystals $\frac{1}{4}$ inch $\times \frac{1}{4}$ inch in cross section cooled by contact with a copper finger to near liquid helium temperature. The masers were operated using an FX-100 xenon flash lamp focused on the specimen by an f/1 spherical mirror. The electrical power input required for oscillations at the maser threshold was about 50 joules. The output was recorded with a PbSe detector operating at 300°K with a time constant of 15 μsec. In Fig. 4(a) the lamp pulse is shown. The maser operating just above threshold is shown in Fig 4(b). Since the fluorescent lifetime of the $^2F_{5/2}$ state is long (4 msec)[5] at threshold the maser starts just at the end of the lamp pulse. Fig. 4(c) and 4(d) shows the maser outputs for inputs much above threshold. With the 15 μsec time constant detector, no maser relaxation oscillations can be seen. Experiments are in progress to observe directly absorptions from the excited $^2F_{5/2}$ state and thus verify the explanation for the three level operation.

The authors are indebted to D. S. McClure for suggesting this system. The contributions of P. N. Yocom for the preparation of the materials and M. Kestigian, P. G. Herkart, and H. E. Temple for growing the CaF_2 crystals are gratefully acknowledged. The many discussions with G. Goldsmith, H. R. Lewis, and J. P. Wittke were most valuable.

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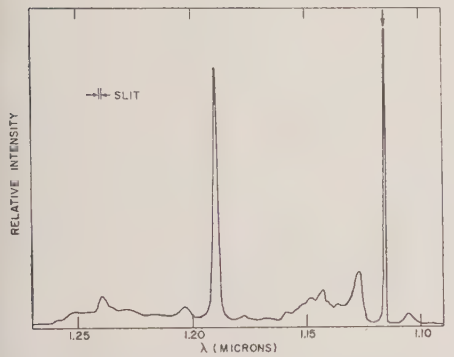

Fig. 1—Fluorescence spectra of $CaF_2:Tm^{2+}$ at 77°K. The maser line (at 4.2°K) is marked with an arrow.

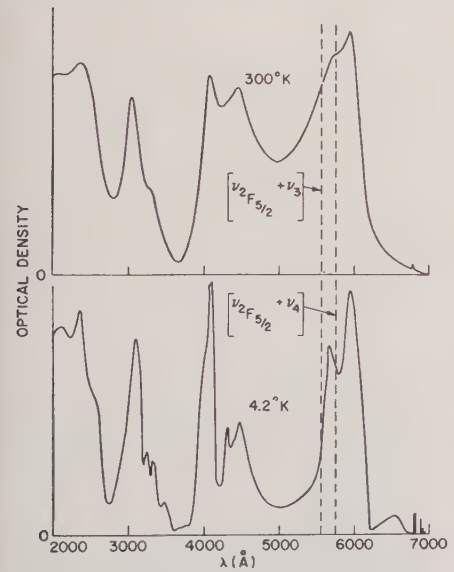

Fig. 2—Band absorption spectra of $CaF_2:Tm^{2+}$ at 300°K and 4.2°K. The frequencies $\nu_{^2F_{5/2}}+\nu_3$ and $\nu_{^2F_{5/2}}+\nu_4$ are indicated.

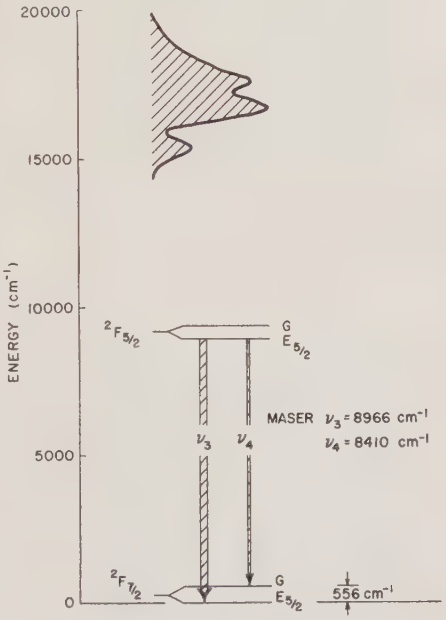

Fig. 3—Energy level diagram for $CaF_2:Tm^{2+}$ showing the maser transition.

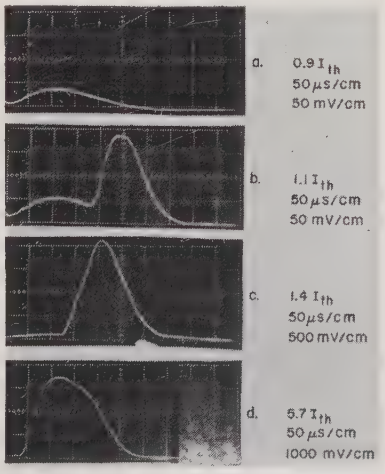

Fig. 4—Pulsed maser output from $CaF_2:Tm^{2+}$ at 1.116 μ at 4.2°K. I_{th} is flash lamp energy at threshold.

Γ-Dependence of Varactor Frequency Doublers*

The dependence of varactor frequency-conversion efficiency upon varactor nonlinearity[1] Γ as predicted by Utsunomiya and Yuan in a recent paper[2] has been the subject of an investigation reported in this letter. As indicated below, the results have affirmed the efficacy of using high-Γ varactors in frequency multiplication. On the basis of the technique described in the cited paper, a systematic calculation of optimum efficiency η_{opt} versus Γ for a frequency doubler was performed. The solid line in Fig. 1 illustrates this relationship for which fixed circuit (and varactor) losses were assumed. It may be noted that η_{opt} is independent of Γ only in the lossless case, in which case $\eta_{opt} \equiv 100$ per cent.

A subsequent investigation using three

* Received, January 8, 1962. The research described in this paper stems from a project sponsored by the Rome Air Development Center, Air Force Systems Command, Griffiss Air Force Base, New York, N. Y., under Contract AF 30(602)-2233.

[1] $C(V) = \dfrac{C_1}{(V+\phi)^{\Gamma}}$,

where Γ is defined as the nonlinearity of the varactor, V = terminal voltage on the varactor, C_1 = value of the varactor capacitance for $(V+\phi) = 1$ volt and ϕ = contact potential of the varactor junction.

[2] T. Utsunomiya and S. Yuan, "Theory, design and performance of maximum efficiency variable reactance frequency multipliers," Proc. IRE, vol. 50, pp. 57–65; January, 1962.

[3] Z. J. Kiss and R. C. Duncan, Jr., "Pulsed and continuous optical maser action in $CaF_2:Dy^{2+}$," this issue, pp. 1531–1532.

[4] G. D. Boyd and L. F. Johnson (private communication) have also obtained maser oscillations in this system.

[5] Z. J. Kiss, *Phys. Rev.*, in press.

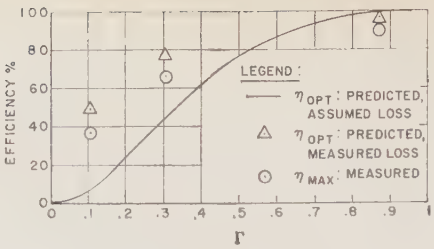

Fig. 1.

TABLE I

Varactor Type	Γ	η_{opt} (%) Predicted	η_{max} (%) Measured	% Bandwidth
MA-4323D (in parallel with 5 pfd)	0.105	49.9	36.2	1.34
PSI-PC-135	0.306	76.5	66.1	2.9
PSI-Hypersensitive Varicap #723*	0.865	98.2	90.1	11.2

* The "Hypersensitive" Varicap was very kindly furnished by J. F. Williams, Applications Engineer, Pacific Semiconductors, Inc., Lawndale, Calif.

varactors, each possessing a different Γ, has lent experimental support to the theoretical prediction. A frequency doubler (10 Mc–20 Mc) was constructed and, for each varactor, the conversion efficiency was maximized by the judicious choice of bias and load resistance. (See Table I and circled points on Fig. 1.)

At the same time, a prediction of η_{opt}, based on the theory, was made for each of the three varactors on the basis of varactor Q and measured circuit losses. (See Table I and points enclosed by triangles on Fig. 1.) Note that these points do not fall on the solid line inasmuch as losses different from those in the assumed case obtained.

Further, it is interesting to note that the percentage bandwidth increases with Γ, an indication of increasing conversion resistance.

We may therefore assert that, although the η vs Γ relationship is affected by many variables, a high Γ provides the potential for higher efficiencies than a low Γ. For any Γ there is an η_{opt} which we recognize as the limiting case and the one toward which any experimental effort ought to be directed.

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A Hot Electron Transistor*

Recently Spratt, Schwartz and Kane[1] described a structure consisting of layers of gold, 20 Å thick aluminum oxide, and 100 Å thick aluminum deposited on germanium which exhibited current transfer when biased as an *n-p-n* transistor with the gold as emitter, aluminum as the base and germanium as the collector. The mechanism was stated to be injection of hot electrons by tunneling from the gold through the insulator into the aluminum base, their transport across the base, and their collection by the germanium-aluminum junction. This interpretation has been questioned on two grounds: the mean free path of hot electrons in a metal might be very small, and possible pinholes in the base metal might introduce spurious effects. Pinholes frequently exist in thin evaporated layers, and since the insulator (aluminum oxide) was formed by oxidation of the evaporated aluminum base, their presence would result in the gold being in direct contact with the germanium.

Recent work of Spitzer, Crowell, and Atalla[2] has indicated a mean free path of about 740 Å for one volt hot electrons in gold. In view of these results, it appeared worthwhile to build an experimental structure utilizing a gold base and a fabrication technology that would greatly reduce the possibility of the occurrence of coincident pinholes in the base metal and insulator.

A gold film approximately 100 Å thick and 0.040 in. in diameter was evaporated on a suitably cleaned n type, 1 Ωcm silicon substrate. The resulting barrier gave good rectification. The reverse current was less than 10^{-5} a at 10 v. Over the entire surface silicon monoxide about 40 Å thick was then evaporated. The emitter contact consisted of a mercury ball squeezed out of a metal tube as indicated in Fig. 1. The diameter of the mercury-silicon contact was approximately 0.015 in. Use of mercury as an emitter contact provided shock absorption and detection of large pinholes in the insulator. When there was a pinhole sufficiently large to admit Hg, the underlying gold film was amalgamated causing the collector characteristic to deteriorate.

Measurements on more than 10 units indicated the incremental common-base forward current gain (α) for most of the units to be about 0.5 at an emitter current of 20 ma. The common-emitter current gain β was consistent with the observed α. From Spitzer, Crowell and Atalla's value of 740 Å for the mean penetration length of hot electrons in Au, the expected α with unity injection and collection efficiencies is 0.87. When the emitter was made positive with respect to the base, no current transfer was observed. The observed results can be explained by a hot electron transport mechanism and, in fact, it is difficult to postulate other mechanisms.

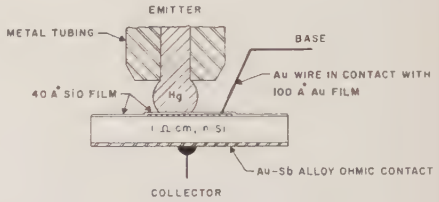

Fig. 1—Hot electron transistor schematic structure.

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Double-Pumped *X*-Band Parametric Amplifier with Extremely Large Gain-Bandwidth Product*

A new parametric amplifier concept has been evolved, which provides very substantial increase in the gain-bandwidth performance and stability of such devices. The concept involves the use of two (or more) independent pump sources at different frequencies and when applied to an *X*-band parametric amplifier, resulted in gain-bandwidth product of almost 6000 Mc. This is, to the author's knowledge, the largest gain-bandwidth product ever obtained from a parametric amplifier.

The parametric amplifier consists of a reduced-height K_u-band and X_L-band waveguide, joined end to end. The varactor is mounted in the X_L waveguide. Two klystrons coupled by a 3-db directional coupler supply pump power through the K_u-band waveguide port.

Two different types of varactors were subsequently used in the experiments: Microwave Associates silicon varactor type MA-4252 (junction capacitance 1 pf), and Microstate Corporation gallium arsenide varactor type MS2505 (junction capacitance 0.95 pf). The self-resonant frequency of the

* Received March 2, 1962.

[1] J. P. Spratt, R. F. Schwartz and W. M. Kane, "Hot electrons in metal films: injection and collection," *Phys. Rev. Lett*, vol. 6, pp. 341–342; April, 1961.

[2] W. G. Spitzer, C. R. Crowell and M. M. Atalla, "Mean free path of photoexcited electrons in gold," *Phys Rev. Lett*, vol. 8, pp. 57 58; January, 1962.

* Received March 12, 1962; revised manuscript received March 26, 1962.

silicon varactor was 7200 Mc which was also the idler frequency of the amplifier. The signal frequency was in this case about 6000 Mc, as dictated by the frequencies of the available pump klystrons. The frequencies of the pump klystrons were adjusted to 13,350 Mc and 13,890 Mc, respectively. This resulted in a bandwidth of 680 Mc (centered at 6000 Mc), with 10-db gain, as limited by the available pump power. It was observed that the bandwidth does not decrease with higher pump power (and thus gain) but actually increases. The maximum bandwidth obtained with one pump only was 370 Mc for 10-db gain.

Because it was hoped that perhaps gallium arsenide varactor would require less pump power, the parametric amplifier was slightly modified and the silicon varactor replaced by the gallium arsenide varactor. The self-resonant frequency of this varactor was 9200 Mc. Since the highest frequency of the klystrons used was 15 Gc, it was necessary to use additional tuning elements to resonate the varactor at 7500 Mc idler frequency and simultaneously at the signal frequency of 7200 Mc. Although the additional tuning elements decreased the bandwidth of the amplifier considerably, such an arrangement made it possible to use the available pump sources and circulator.

Figs. 1, 2 and 3 show the gain-bandwidth performance of the single- and double-pumped amplifier with gallium arsenide varactor, as obtained with swept signal generator on the input side and an X-band traveling-wave tube, followed by a detector, on the output side of the parametric amplifier-circulator combination. With the exception of pump power adjustments (*i.e.*, reducing the power of pump #1 and turning off pump #2) no adjustments of any kind were made in going from the double- to single-pump case.

The figures dramatically illustrate the tremendous increase of the gain-bandwidth by double-pumping. The gain-bandwidth product for the single-pump case is about 120 Mc, while in the double-pumped case it is about 5850 Mc, *i.e.*, 48 times larger. It should be pointed out that the gain was limited in the single-pump case by oscillations, while in the double-pumped case the amplifier was stable within 2 db over 8-hour periods (using commercially available pump klystron power supplies) and the gain was limited by the total available pump power, not by instability.

The over-all noise figure of the circulator, double-pumped parametric amplifier (adjusted for 40-db gain), traveling-wave tube combination was measured to be 1.7 db, which includes 0.3-db insertion loss of the circulator. The noise figure of the same system, but with the parametric amplifier driven by only one pump and adjusted for 20-db gain, was 3.4 db. Although the main reason for this larger noise figure is the effect of the second-stage noise figure (due to the smaller gain of the single-pumped parametric amplifier), the measurements show that double-pumping has positive effect not only on the bandwidth and stability of a parametric amplifier, but improves as well its noise performance.

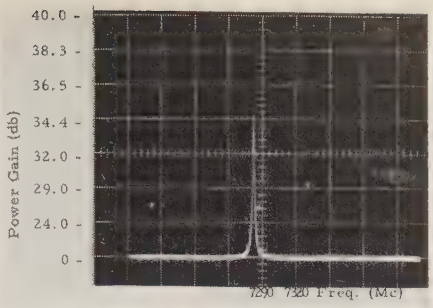

Fig. 1—Gain-frequency characteristics with one pump at 14,820 Mc. $G^{1/2}B \approx 120$ Mc, gain-limited by oscillations.

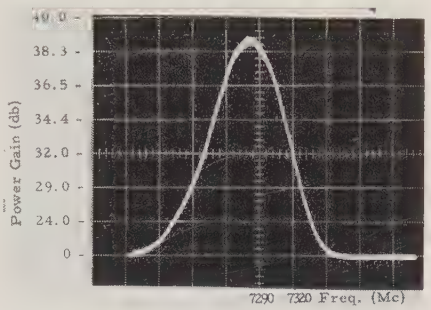

Fig. 2—Gain-frequency characteristics with two pumps at 14,820 Mc and 14,827 Mc. $G^{1/2}B \approx 5000$ Mc, gain-limited by the available pump power.

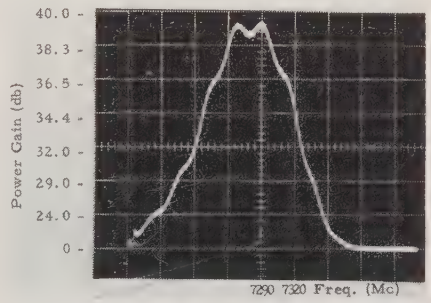

Fig. 3—Gain-frequency characteristics with two pumps at 14,812 Mc and 14,836 Mc. $G^{1/2}B \approx 5800$ Mc, gain-limited by the available pump power.

It is believed that the measured performance of the double-pumped parametric amplifier is very remarkable, considering the fact that the varactors used were off-the-shelf items with relatively large junction capacitance and the negative bias was only 0.4 volt, dictated by the available pump power.

The reported result is one of large number of similar experiments made by the author and others in the General Motors Corporation during the past year. The experiments involved frequencies from VHF to X band and all confirmed the above findings, that is, that double-pumping improves very substantially the bandwidth, gain and noise figure of negative-resistance parametric amplifiers. Theoretical reasons for this improvement are known and they will be described in a separate paper, to be submitted for publication shortly.

The author is indebted to R. F. Brewster for helpful discussions.

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Linear FM Pulse Compression Doppler Distortion Effects*

We have noted with interest the communication of Ramp and Wingrove,[1] commenting on a previous note,[2] in which they offer a "more exact model of the Doppler effect" for linear FM pulse compression. The model chosen by Ramp and Wingrove does give a better description of the Doppler effect on the signal, but does not provide the best prediction of the total Doppler effect when a normal combination of signal and receiver is assumed.

A better model, based on previously published work, can be constructed.[2,3] Further the "fundamental limitation" they obtain is the result of the filtering technique they assume, and is not a fundamental limitation, *per se*, of linear FM pulse compression, as they contend. The two correspondences do not describe precisely the same signal as it appears at the transmitting antenna, and there are differences in the compression filter, as were noted by Ramp and Wingrove. The salient points of each model are summarized below:

Matched Filter	*Ramp and Wingrove*
Signal	
a) Rectangular time function	Rectangular spectrum
b) Linear FM	Square law phase
c) Nondispersive Doppler shift	Dispersive Doppler shift
Filter	
d) Band-limited, matched amplitude and phase	Unlimited bandwidth, square law phase match only (linear time delay vs frequency).

Over a broad range of parameters the assumptions a) through c) yield results that differ only in second order and higher terms. Assumption c) of Ramp and Wingrove represents a more exact model of the Doppler effect, while assumptions a) and b) represent a less exact model of the signal function. Assumption d) of these correspondents, however, opens the question of the general usefulness of this particular approach.

The model of Ramp and Wingrove applies primarily when the signals have large fractional bandwidth (low carrier fre-

* Received December 6, 1961.

[1] H. O. Ramp and E. R. Wingrove, "Performance degradation of linear FM pulse compression systems due to the Doppler effect," Proc. IRE (*Correspondence*), vol. 49, p. 1693; November, 1961.

[2] C. E. Cook, "General matched filter analysis of linear FM pulse compression," Proc. IRE (*Correspondence*), vol. 49, p. 831; April, 1961.

[3] J. R. Klauder, A. C. Price, S. Darlington and W. J. Albersheim, "The theory and design of Chirp radars," *Bell Sys. Tech. J.*, vol. 39, pp. 745–808; July, 1960.

quency), very large compression ratios, and when very large radial velocities are encountered. The model of Cook applies when the product of the compression ratio and radial velocity is more moderate, thus insuring that the dispersive Doppler factor is negligible ($K\nu < \frac{1}{2}$ using the notation of Ramp and Wingrove). Fig. 1 plots results derived from the nondispersive Doppler, matched filter model [equation (10) of Cook[2]] which shows the waveform distortions caused by moving targets when the appropriate conditions apply. A wide bandwidth linear time delay model produces only a time shift at the compression filter output with no pulse shape distortion when the dispersive factor is small. In general, the pulse compression filter is followed by an even narrower spectrum-shaping filter in order to reduce the signal sidelobes. Thus, predicting system results on the basis of an unlimited band-pass characteristic under any Doppler conditions would be somewhat hazardous.

The dispersive effect of high velocity targets which Ramp and Wingrove have derived is equivalent to the quadratic phase distortion (*i.e.*, linear FM sweep mismatch) considered by Klauder, Price, Darlington and Albersheim.[3] Klauder, *et al.*, have calculated the effects of this type of distortion for nonband-limited and band-limited cases, and conclude that the compressed pulse output is less sensitive to this type of distortion when a narrow-band, spectrum-shaping filter is used.

Using the illustrative values assumed by Ramp and Wingrove, the quadratic phase error at band edge is $\pi/2$ radians. This case is shown in Fig. 35 of Klauder, *et al.*, for a nonband-limited linear FM signal, and in Fig. 30 for the band-limited signal. The distortion is much less severe for these signals than for the Gaussian signal illustrated by Ramp and Wingrove. If, however, the quadratic phase distortion is increased to 2π radians at band edge, the nonband-limited linear FM signal undergoes severe distortion, and exhibits a double peak structure as can be seen in Fig. 36 of Klauder, *et al.* Fig. 2 illustrates compressed pulse waveforms for the unlimited band-pass case with quadratic phase errors of 0, $\pi/2$ and 2π radians respectively. Fig. 3 shows compressed pulse waveforms when band shaping is used to reduce sidelobes to greater than 30 db down for the same phase errors. The distortion effects shown in Fig. 3 are seen to be less serious for the larger phase error. These waveforms provide experimental verification of the theoretical results obtained by Klauder, *et al.* Direct comparison of the results of the Gaussian pulse case of Ramp and Wingrove with the rectangular pulse case may be made if the phase error term $\nu K\pi/2$, of their equation (7), is increased by approximately a factor of 4 (*i.e.*, a $\pi/2$ phase error for the Gaussian case corresponds roughly to the 2π phase error of the rectangular pulse, band-limited case). It would appear that coupling this analytical approach with the shift of the center of the spectrum would lead to a more effective model for considering high-velocity Doppler effects.

In conclusion, Ramp and Wingrove have made an incomplete statement in asserting that the dispersive Doppler model reveals a fundamental limitation of linear FM pulse compression. The fundamental limitation can be ascribed to matched filters as a class if the filter is to be matched to the transmitted signal. Some signals may be less seriously affected than others; thus a "fundamental limitation" of a particular signal is a relative conclusion that should be supported by comparison with other matched filter signal structures. These degradations can be avoided, of course, if the filter is matched to the received signal as, for example, when *a priori* velocity information is available or a velocity search is instituted. The necessary match can be made either by modifying the phase-vs-frequency slope of the filter, or by suitably predistorting the transmitted signal.

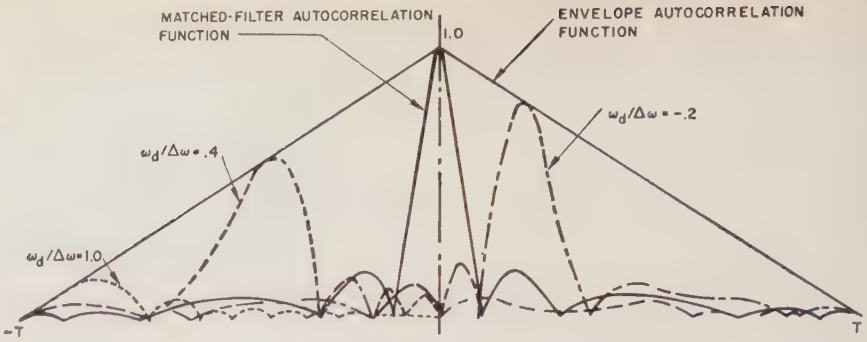

Fig. 1.

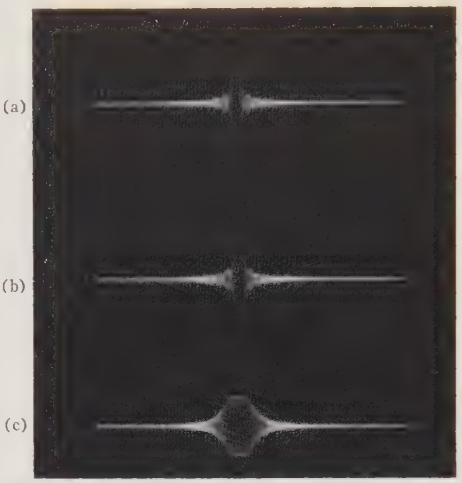

Fig. 2.

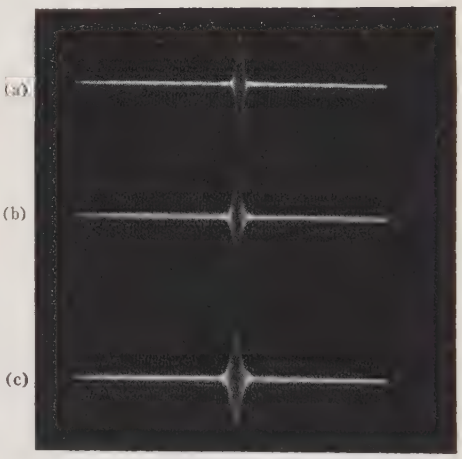

Fig. 3.

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Authors' Comment[4]

Our answer to the criticism by Cook and Heiss begins with a restatement of the main point of our correspondence: for a sufficiently high value of the *product* $K \cdot \nu$, a linear FM pulse compression system loses its singular advantage, namely, that one filter can be used to compress returns from all targets regardless of their velocities. We consider that the loss of this advantage constitutes a "fundamental limitation" of linear FM pulse compression. We apologize to our readers for not stating this point explicitly in our correspondence. We erroneously assumed that this would be obvious, at least to those versed in the art.

Cook and Heiss criticize us for representing the rectangular-envelope, linear FM signal by a rectangular amplitude spectrum and parabolic phase spectrum. We would like to remind Cook, however, that he states in a previous paper[5] that for a large time-bandwidth product, the rectangular-envelope, linear FM signal has essentially the spectrum we assume. We have used this representation not only for mathematical convenience, but also because we believe that it more accurately describes the waveform that would be generated and matched in a practical system. The same conclusions are also reached by Klauder, *et al.*, page 771.[3]

Cook and Heiss question the validity of an analysis which assumes an infinite bandwidth compression filter. First, we have *not* assumed an infinite bandwidth for our rigorous analysis, but only for the estimation of the pulse widening effect based on a Gaussian spectrum. Second, even had we used unlimited bandwidth in our rigorous case, the difference would have been in the SNR,

[4] Received December 21, 1961.
[5] C. E. Cook, "Pulse compression—key to more efficient radar transmission," Proc. IRE, vol. 48, pp. 310–316; March, 1960. See especially p. 311.

which we did not consider, and not in the output waveform shape. This point is also brought out in Klauder, *et al.*, on page 769.[3]

We do not doubt that the analysis of Cook and Heiss is adequate when the product $K \cdot \nu$ is small, and we are aware that pulse distortion will occur as the Doppler-shifted signal slides out of alignment with a North-matching filter. The purpose of our correspondence is to show that when the product $K \cdot \nu$ is large, dispersive effects occur that distort the compressed pulse in addition to any distortion due to weighting. We do not agree, however, that these dispersive effects are of second order for any $K \cdot \nu$, as implied by Cook and Heiss.

They suggest that "coupling" the analytical approach of Klauder, *et al.*, on pages 790–795,[3] with a spectrum shift, "would lead to a more effective model" for considering the dispersive effects of Doppler. We will now show that this is indeed the model which we have used. Our equation (4) can be rewritten as follows:

$$0(\omega) = \text{rect.}\,\frac{\omega - \bar{\omega}_c}{\bar{\Omega}} \exp j[\theta + (d_1 - c_1\nu - 2a\nu\bar{\omega}_c)\omega]$$

$$\cdot \exp j[-(2-\nu)a\nu(\omega - \bar{\omega}_c)^2] \qquad (8)$$

where

$$\nu = \frac{2v_r}{c};$$

$$\bar{\omega}_c = (1+\nu)\omega_c; \qquad \bar{\Omega} = (1+\nu)\Omega\cdot$$

$$\theta = d_0 - d_1\omega_c + (2-\nu)a\nu(1+\nu)^2\omega_c^2.$$

In the time domain:

$$o(t) = \left\{\text{sinc}\left[\frac{\bar{\Omega}}{2}(t - d_1 + c_1\nu + 2a\nu\bar{\omega}_c)\right]\right.$$

$$\left.\cdot \cos\left[\bar{\omega}_c(t - d_1 + c_1\nu + 2a\nu\bar{\omega}_c) - \theta\right]\right\} *$$

$$\left\{\int_{-\infty}^{\infty} \exp j\omega t\right.$$

$$\left.\cdot \exp j[-(2-\nu)a\nu(\omega - \bar{\omega}_c)^2]d\omega\right\}. \qquad (9)$$

The first part of the convolution is easily recognized as a function having the same form as (92).[3] Notice that the carrier frequency $\bar{\omega}_c$ contains the proper velocity-dependent "spectrum shift." Also, the time origin is shifted an amount determined by the target range and velocity. The second part of the convolution brings in a quadratic phase distortion equivalent to that of (97).[3] Since we have included no amplitude weighting, our model is identical to that of Klauder, *et al.*, with their F_1 set equal to zero.

The envelope of $o(t)$ (104)[3] is plotted in Figs. 33–36[3] for the case of $F_1 = 0$, with the phase shift at the edge of the band ϕ as parameter. By equating the coefficient of the quadratic phase term in (9) to the corresponding coefficient in (103),[3] the phase at the edge of the band can be expressed in terms of a and ν:

$$\phi = (2-\nu)a\nu\left(\frac{\bar{\Omega}}{2}\right)^2. \qquad (10)$$

Since $a = T/2\Omega$, (10) becomes

$$\phi = \frac{\pi}{4}(2-\nu)\nu(1+\nu)^2K \approx \frac{\pi}{2}\nu\cdot K$$

$$(\text{for } \nu \ll 1). \qquad (11)$$

Fig. 35[3] shows that for $\phi = \pi/2$, considerable distortion results. If this distortion is taken to be the maximum allowable, the $K \cdot \nu$ product is restricted to values less than one. This is the same conclusion resulting from the estimate in our correspondence, indicating the validity of the estimate.

Eq. (11) shows that the dispersion due to Doppler, and thus the pulse distortion, depends solely on the *product* $K \cdot \nu$ and not on K or ν alone, and certainly not on the fractional bandwidth as implied by Cook and Heiss. (The fractional bandwidth is somewhat restricted by the mathematical routine, in that the negative frequencies are neglected.) If Cook and Heiss carry through their analysis without neglecting the dispersive effect of Doppler, they will arrive at the same conclusion, namely, that a distortion dependent on $K \cdot \nu$ results. This distortion is due to the nature of the Doppler effect and does not depend upon the model used for analytical purposes.

Future—and perhaps not so future—radar- and sonar-systems must deal with the problem arising from the dispersive Doppler effect. Of course, we are aware that *a priori* velocity information or a Doppler filter bank can, in theory, be used with linear FM pulse compression with no limitation on $K \cdot \nu$. If one is willing to go to the expense and complexity of these techniques, then a linear FM signal is not the optimum waveform. The search for this optimum waveform is the subject of a further paper by Klauder.[6] We believe, however, that a better solution is to use a waveform not suffering from the "fundamental limitation" of linear FM, in other words, a waveform that *can* be phase-matched by a single filter for all target velocities. Fortunately, such a waveform does exist.

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General Electric Co.
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[6] J. R. Klauder, "The design of radar signals having both high range resolution and high velocity resolution," *Bell Sys. Tech. J.*, vol. 39, p. 809; July, 1960.

Additional Comments by Cook and Heiss[7]

We feel that Ramp and Wingrove have not addressed themselves directly to several of the points we raised, and therefore summarize our position as follows:

1) We based no major criticism on the spectrum shape approximation, but rather were concerned with the emphasis placed on attributing the pulse distortion effects solely to the dispersive Doppler characteristic, especially since the example cited by Ramp and Wingrove represents an extreme case.
2) Eq. (2) of the authors' original correspondence[1] is, for all practical purposes, an unlimited bandwidth situation for computing effects on the pulse shape. The modification made in their comment still neglects the effects of band-limiting normally used to achieve pulse sidelobe reduction. We are well aware that the distortion effect they discuss is independent of fractional bandwidth. However, what Klauder, *et al.*[3] have derived analytically, and what we have shown experimentally, is the fact that a narrow-band spectrum weighting filter markedly reduces the degree of distortion caused by the quadratic FM error. The point we then made was that for a great range of parameters the distortion effects most noticeable would be those that are related to the fractional bandwidth, such as that caused by the spectrum sliding out of the effective receiver bandpass. Thus, we still feel that their model is most useful in the high compression ratio, comparatively large fractional bandwidth case.
3) We wished to point out that the quantitative analysis which Ramp and Wingrove were seeking had been previously published by Klauder, *et al.*[3] in rather thorough detail.
4) At no point did we suggest that linear FM pulse compression was an optimum signal. (Indeed, it would be difficult to describe an optimum signal without knowing the intended application.) Neither did we say that this type of signal had no limitations. What we did say, by implication, was that Ramp and Wingrove's use of the phrase "fundamental limitation" was unfortunate since any matched filter signal will be subject to restrictions of more or less serious nature, depending on the application of the signal involved. Thus, we suggested that the term "*fundamental* limitation" should be applied to matched filters as a class, and that the particular manifestation of this limitation must be compared to some specific matched filter standard, a concept that should not be considered unusual.

Reply of Ramp and Wingrove[8]

Cook and Heiss are concerned that our latest communication is not directly addressed to the several points raised by them. For the most part those points pertain to small compression ratios and are not relevant to the question at hand. Since the sec-

[7] Received January 26, 1962.

[8] Received February 14, 1962.

ond round of correspondence has not raised any new issues, we direct the interested reader to the prior correspondence to determine for himself whether or not we have properly treated the major issue and whether the remaining issues are irrelevant.

If our use of the term "fundamental limitation" was not understood by the reader, we again apologize. In our context, "fundamental" carried perhaps a stronger "economic fact-of-life" implication than a precise scientific meaning. If Cook and Heiss still feel the need for defining fundamental limitation for the class of matched filters, they should do so.

The quantitative analysis which we were seeking was one yielding an explicit expression for the pulse widening due to Doppler dispersion for a nonweighted pulse. This analysis was not published by Klauder, *et al.* Their figures, however, as well as those of Young[9] can be applied to the problem which we treated.

We wish to re-emphasize one significant conclusion (also not stated or implied by Klauder, *et al.*) which is: for sufficiently high values of $K \cdot \nu$, dispersive Doppler distortion leads to a pulse widening which reduces the effective compression ratio in linear FM pulse compression systems. We concur that for a large range of parameters, other sources of distortion override or mask the dispersive Doppler distortion. Our analysis was intentionally designed to eliminate these other sources of distortion in order to isolate and emphasize dispersive Doppler distortion. We maintain that for the not unrealistic case of $K \cdot \nu$ approaching unity, dispersive effects strongly limit the usefulness of the linear FM pulse compression technique.

[9] R. T. Young, Jr., "Fourier Analysis of Pulses with Frequency Shifts During the Pulse," M.I.T. Rad. Lab., Cambridge, Mass., Rept. No. 52-5; January 30, 1943.

Simulation of Third-Order Systems with Double-Lead Using One Operational Amplifier*

In previous communications on the same subject, two particular cases of the general third-order linear systems were considered. The purpose of this note is to present yet another particular type, that is, a third-order system with double-lead which has a transfer function of the form

$$F(S) = -\frac{b_2 S^2}{(a_3 S^3 + a_2 S^2 + a_1 S + 1)}. \quad (1)$$

As already discussed, if the admittances (Y's) are properly chosen, third-order systems can be simulated with the network of Fig. 1, the transfer function of which can be shown to be

$$\frac{E_0}{E_1} = -\frac{Y_1 Y_3 Y_5}{Y_6(Y_1 + Y_2 + Y_3)(Y_3 + Y_4 + Y_5 + Y_7) + Y_3 Y_6(Y_4 + Y_5 + Y_7) + Y_5 Y_7(Y_1 + Y_2 + Y_3 + Y_8) + Y_3 Y_5 Y_8}. \quad (2)$$

Of the possible four circuits, each employing three capacitors and five resistors, only three are shown in Fig. 2. The conditions under which these circuits can simulate the given third-order system are also listed in Fig. 2 alongside of the respective circuits. The details regarding the derivation of these validity conditions will be discussed in another communication.

Simulation of the system as characterized by (1) with the network of Fig. 1 would require at least three capacitors. A posisble choice, as shown in Fig. 2(a), is to make

$$\left.\begin{aligned} Y_3 &= SC_3 \\ Y_5 &= SC_5 \\ Y_7 &= SC_7 \\ \frac{Y_1}{2} = Y_2 = Y_4 = Y_8 &= \frac{1}{R} \\ Y_6 &= \frac{1}{aR} \end{aligned}\right\}. \quad (3)$$

Substituting (3) into (2) and simplifying

$$\frac{E_0}{E_1} = -\frac{\frac{a}{2} R^2 C_3 C_5 S^2}{\frac{a}{4} R^3 C_3 C_5 C_7 S^3 + \left[\frac{(a+1)}{4} R^2 C_3 C_5 + aR^2 C_5 C_7 + \frac{1}{4} R^2 C_3 C_7\right] S^2 + [5RC_3 + 4RC_5 + 4RC_7] S + 1}. \quad (4)$$

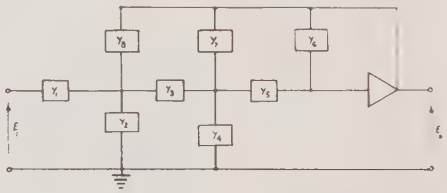
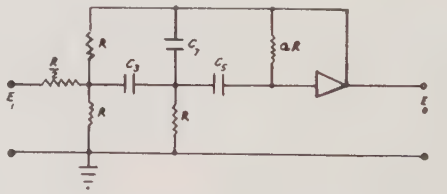


Fig. 1—Block diagram of an operational amplifier and its associated input feedback networks for the simulation of third-order systems.



$$b_2 = \frac{a}{2} R^2 C_3 C_5, \qquad a_1 = 5RC_3 + 4RC_5 + 4RC_7, \qquad a_2 = \frac{(a+1)}{4} R^2 C_3 C_5 + aR^2 C_5 C_7 + \frac{1}{4} R^2 C_3 C_7,$$

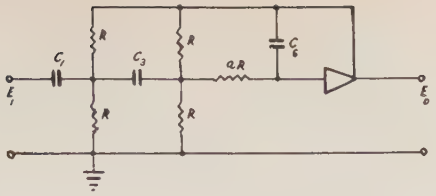
$$a_3 = \frac{a}{4} R^3 C_3 C_5 C_7, \qquad a_1 > \frac{8a_3}{b_2}, \qquad 2a_2 > b_2 > 32\left(\frac{a_3}{2a_2 - b_2}\right)^2, \text{ and either}$$

$$\frac{b_2(2a_2 - b_2) + \sqrt{b_2^2(2a_2 - b_2)^2 - 32a_3^2 b_2}}{2a_3} > \left(\frac{a_1 b_2 - 8a_3}{5b_2}\right) > \frac{b_2(2a_2 - b_2) - \sqrt{b_2^2(2a_2 - b_2)^2 - 32a_3^2 b_2}}{2a_3}$$

or $$\left(\frac{a_1 b_2 - 8a_3}{5b_2}\right) > \frac{b_2(2a_2 - b_2) + \sqrt{b_2^2(2a_2 - b_2)^2 - 32a_3^2 b_2}}{2a_3} \quad \text{and} \quad 4p^3 + 27q^2 < 0$$

Fig. 2. (*Con't next page*)

* Received by the IRE, November 6, 1961.



$$b_2 = \frac{1}{2} R^2C_1C_3, \quad a_1 = \frac{1}{2} RC_1 + RC_3 + (2a+1)\,RC_5, \quad a_2 = \frac{(2a+1)}{2} R^2C_1C_5 + \frac{(4a+1)}{2} R^2C_3C_5,$$

$$a_3 = \frac{a}{2} R^3C_1C_3C_5. \quad a_1 > \frac{2a_3}{b_2}, \quad b_2 > \left(\frac{4a_3}{a_2}\right)^2, \quad (a_1b_1 - 2a_3)^2 > 4b_2^3.$$

and either

$$OQ > OB > OP > OA$$

or

$$OB > OQ > OA > OP$$

or

$$OQ > OB > OA > OP \quad \text{and} \quad \Delta < 0$$

or

$$OB > OQ > OP > OA \quad \text{and} \quad \Delta > 0$$

where

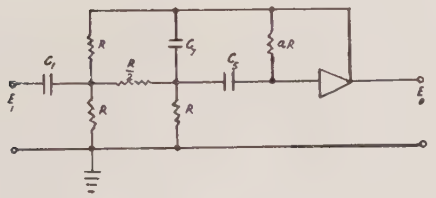
$$OA = \frac{(a_1b_2 - 2a_3) - \sqrt{(a_1b_2 - 2a_3)^2 - 4b_2^3}}{2b_2}$$

$$OB = \frac{(a_1b_2 - 2a_3) + \sqrt{(a_1b_2 - 2a_3)^2 - 4b_2^3}}{2b_2}$$

$$OP = \frac{a_2b_2 - \sqrt{a_2^2b_2^2 - 16a_3^2b_2}}{4a_3}$$

$$OQ = \frac{a_2b_2 + \sqrt{a_2^2b_2^2 - 16a_3^2b_2}}{4a_3}$$

$$\Delta = I^3 - 27J^2$$



$$b_2 = \frac{a}{4} R^2C_1C_5, \quad a_1 = \frac{3}{8} RC_1 + \frac{1}{4}(a+2)RC_5 + \frac{1}{2} RC_7, \quad a_2 = \frac{1}{8} R^2C_1C_5 + \frac{1}{8} R^2C_1C_7 + \frac{a}{2} R^2C_5C_7$$

$$a_3 = \frac{a}{8} R^3C_1C_5C_7. \quad a_1 > \frac{a_3}{b_2}, \quad b_2 > \left(\frac{2a_3}{a_2}\right)^2, \quad (a_1b_2 - a_3)^2 > \frac{3}{2} b_2^3,$$

and either

$$OQ > OB > OP > OA$$

or

$$4p^3 + 27q^2 < 0$$

where

$$OA = \frac{4(a_1b_1 - a_3) - \sqrt{16(a_1b_2 - a_3)^2 - 24b_2^3}}{3b_2}$$

$$OB = \frac{4(a_1b_2 - a_3) + \sqrt{16(a_1b_2 - a_3)^2 - 24b_2^3}}{3b_2}$$

$$OP = \frac{2a_2b_2 - \sqrt{4a_2^2b_2^2 - 16a_3^2b_2}}{a_3}$$

$$OQ = \frac{2a_2b_2 + \sqrt{4a_2^2b_2^2 - 16a_3^2b_2}}{a_3}$$

$$p = \frac{8}{3}(4a_2 + b_2) - \frac{64}{27} a_1^2$$

$$q = -\frac{128}{3} a_3 + \frac{64a_1(4a_2 + b_2)}{27} - \frac{2}{27}\left(\frac{8a_1}{3}\right)^3$$

Fig. 2—Networks for the simulation of

$$\frac{E_0}{E_1} = -\frac{b_2s^2}{a_3s^3 + a_2s^2 + a_1s + 1}.$$

Eqs. (1) and (4) will be identical if

$$b_2 = \frac{a}{2} T_1T_2 \tag{5}$$

$$a_1 = 5T_1 + 4T_2 + 4T_3 \tag{6}$$

$$a_2 = \frac{(a+1)}{4} T_1T_2 + \frac{1}{4} T_1T_3 + aT_2T_3 \tag{7}$$

$$a_3 = \frac{a}{4} T_1T_2T_3 \tag{8}$$

where

$$\left.\begin{aligned} T_1 &= RC_3 \\ T_2 &= RC_5 \\ T_3 &= RC_7 \end{aligned}\right\}. \tag{9}$$

Simulation of the system of (1) with the network of Fig. 2(a) is possible only if the values of a, T_1, T_2 and T_3 obtained as the solution of (5)–(8) are real and positive. It is therefore, required to determine a, T_1, T_2 and T_3 in terms of the known real and positive constants b_2, a_1, a_2 and a_3.

Eliminating a, T_2 and T_3 from (5)–(8) gives a cubic

$$5T_1^3 - a_1T_1^2 + 8(2a_2 - b_2)T_1 - 64a_3 = 0 \tag{10}$$

which will have either one or three real roots depending on whether its discriminant is positive or negative. It is obvious that (10) can have no negative real roots; therefore, the real root(s) will have to be positive. It can be shown that if

$$\left.\begin{aligned} a_1 &> \frac{8a_3}{b_2} \\ 2a_2 > b_2 &> 32\left(\frac{a_3}{2a_2 - b_2}\right)^2 \end{aligned}\right\} \tag{11}$$

and, either

$$\frac{b_2(2a_2 - b_2) + \sqrt{b_2^2(2a_2 - b_2)^2 - 32a_3^2b_2}}{2a_3} > \left(\frac{a_1b_2 - 8a_3}{5b_2}\right) > \frac{b_2(2a_2 - b_2) - \sqrt{b_2^2(2a_2 - b_2)^2 - 32a_3^2b_2}}{2a_3}. \tag{12}$$

or

$$\left.\begin{aligned} &4p^3 + 27q^2 < 0 \\ &\text{where} \\ &p = \frac{8}{5}(2a_2 - b_2) - \frac{a_1^2}{75} \\ &q = -\frac{64}{5} a_3 + \frac{8}{75} a_1(2a_2 - b_2) - \frac{2}{27}\left(\frac{a_1}{5}\right)^3 \\ &\text{and} \\ &\frac{(a_1b_2 - 8a_3)}{5b_2} > \frac{b_2(2a_2 - b_2) + \sqrt{b_2^2(2a_2 - b_2)^2 - 32a_3^2b_2}}{2a_3} \end{aligned}\right\} \tag{12a}$$

then either one or two sets of positive real a, T_1, T_2 and T_3 exist, depending on whether (12) or (12a) is satisfied, for which the system of (1) can be simulated with the circuit of Fig. 2(a).

Two other circuits and the conditions under which these can simulate the given system of (1) appear in Figs. 2(b) and 2(c).

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A New Approach to Simplified Parametric Amplifier Tuning*

A parametric amplifier has been developed which allows a very convenient means of tuning over extended bandwidths. Utilizing four-frequency operation with wide-band up-conversion gain plus tunable regenerative gain it has been possible to obtain simple one-knob tunability while maintaining low-noise performance.

Conventional diode parametric up-converters involve the control of three frequencies: pump (f_p), signal (f_s), and difference (f_p-f_s) frequencies, or pump, signal, and sum (f_p+f_s) frequencies. The mode of operation chosen for this design is sum-frequency up-conversion (the output is taken at f_p+f_s) with loading at the difference frequency producing regeneration and resultant increased power gain.[1,2,3]

A sketch of the basic sum-frequency up-converter is shown in Fig. 1(a) with the various resonant circuits indicated. This type of amplifier can be tuned to obtain the response indicated in Fig. 1(b). If a restricting section of waveguide, which has a good RF match at both the sum and pump frequencies while being below cutoff at the difference frequency, is inserted at the amplifier output A-A', its position relative to the varactor diode can be adjusted for resonance at the idler frequency. Such an amplifier is sketched in Fig. 2(a) and a typical response of this amplifier is shown in Fig. 2(b). The resonating of the difference frequency produces regenerative gain, and the means chosen for producing it can be varied quite simply to tune the amplifier over a considerable bandwidth.

An experimental amplifier which produces exactly the response desired has been tested. The amplifier operates from 1250 to 1350 Mc with a fixed pump frequency of 8800 Mc and an MA460F varactor diode. It can be tuned over the complete range with an instantaneous bandwidth of 8 Mc and less than 2.0-db noise figure. For this experimental amplifier the tunability was obtained by inserting a dielectric vane in the waveguide section between the diode and the high-pass filter. In Fig. 3 are shown various band-pass responses for this amplifier taken from an oscilloscope presentation. The multiple-exposure picture was taken for different insertions of the dielectric vane, and demonstrates the type of tunability obtained. Package models of this amplifier type have been incorporated with UPS-1 and TPS-10D radar systems for evaluation.

It is also possible to use a ferrite phase shifter in place of the dielectric vane to tune the amplifier electronically.

An advantage of this type of amplifier from an applications viewpoint is as follows. An amplifier which produces wide-band

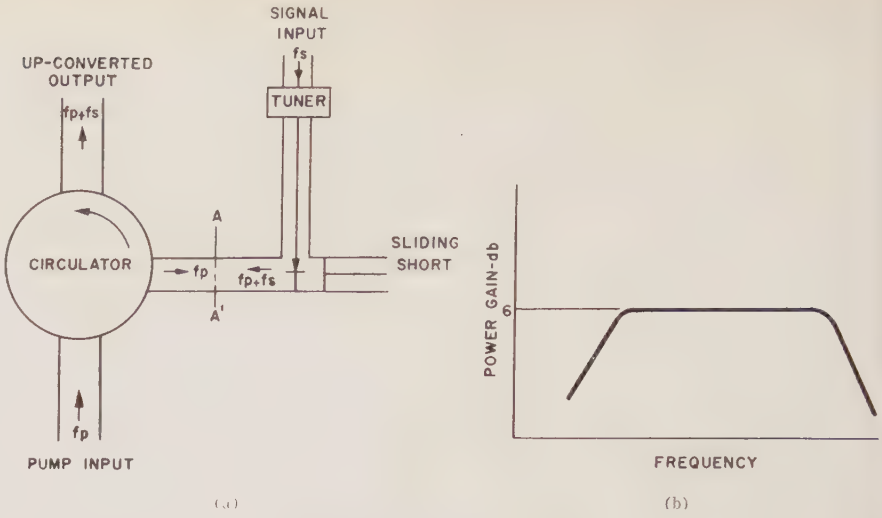

Fig. 1—Sum-frequency up-converter.

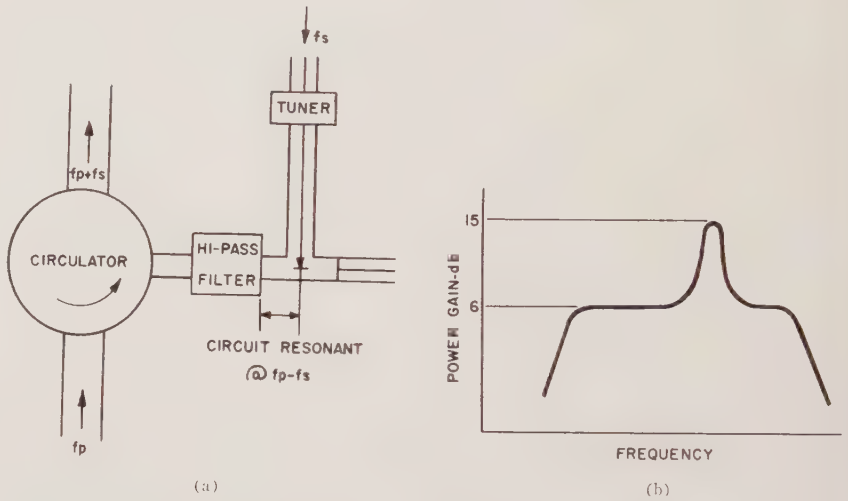

Fig. 2—Four-frequency up-converter.

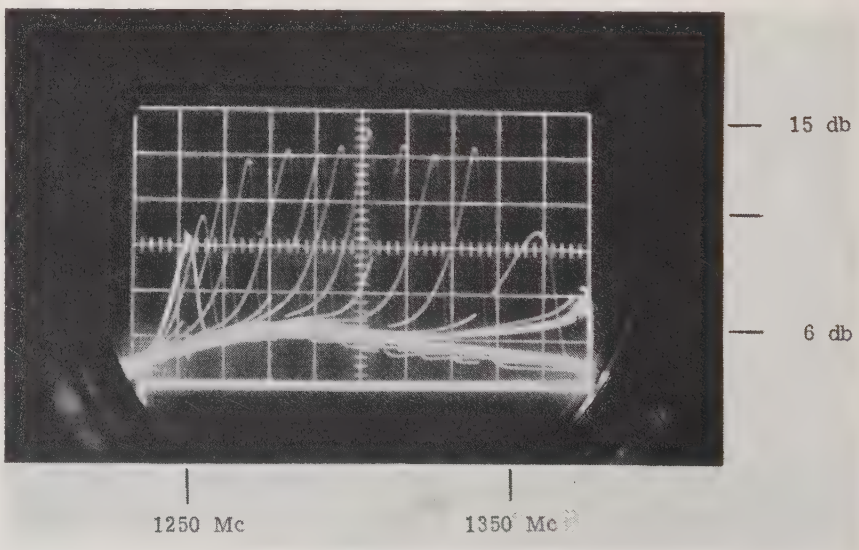

Fig. 3—Band pass of up-converter—experimental curve.

* Received February 26, 1962.

[1] E. M. T. Jones and J. S. Honda, "A low noise up-converter parametric amplifier," 1959 WESCON Convention Record, pt. 1, pp. 99–107.

[2] D. Y. Adams, "An analysis of four-frequency nonlinear reactance circuits," IRE Trans. on Microwave Theory and Techniques, vol. 8, pp. 274–283; May, 1960.

[3] J. A. Luksch, *et al.*, "Design and operation of four-frequency parametric up-converters," IRE Trans. on Microwave Theory and Techniques, vol. MTT-9, pp. 44–52; January, 1961.

gain (say 100 Mc bandwidth) may be unattractive because of image response if used in a superheterodyne receiver, and also because wide-band amplifiers are susceptible to interference problems whether that interference be friendly or unfriendly. The amplifier discussed here allows very rapid tuning of a narrow-band receiver. If electronic tuning is used the amplifier's response can be moved in microseconds.

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28-Ft Liquid-Spun Radio Reflector for Millimeter Wavelengths*

The largest precision parabolic reflector ever successfully fabricated in one piece, and one of the most accurate large reflectors in the world, has been delivered by the Kennedy Antenna Division of Electronic Specialty Company to the Lincoln Laboratory of the Massachusetts Institute of Technology.

It was known from the outset that reliable surface error measurement would be exceedingly difficult to make at the factory, particularly because of the large aperture (670 square feet) and the small magnitude of the surface errors (at most, less than twenty thousandths of an inch). Accordingly, factory measurements were limited to taking "ring" readings, using a wheel-equipped dial indicator held running against the surface at various radii while the "dish" was slowly rotated about its optical axis on the production equipment. 168 such readings were taken at intervals of two feet in radius and 15° in rotation. Computed from these readings, an rms surface error of less than 0.005 in is indicated out to half-radius of the dish, and 0.008 over all. Such ring measurements supply only indirect information as to accuracy in parabolic section. Therefore main reliance was placed upon beam pattern tests at 8.5-mm wavelength to be made by Lincoln Laboratory.

Fig. 1 shows the 28-ft reflector installed on top of the three-story Lincoln Laboratory building in Lexington, Mass. The convenient terrain permitted the establishment of a test range extending 30,000 ft to a high point on the horizon. The feed system, developed at Lincoln Laboratory, is a modified Cassegrainian type with a small plane secondary mirror located just inside the 12-ft focal distance of the paraboloid.

Beam pattern tests at a frequency of 35,200 Mc (8.5-mm wavelength) show a half-power beamwidth of only 4.4 minutes of arc. Sidelobes of the pattern were about 25 db (300 times) lower than the mainlobe. The power gain measured in preliminary tests was 67.4 db, whereas a gain of 68 db is calculated to represent the best performance that can realistically be attained in antenna manufacturing; in fact, the gain of an ideal paraboloid with no sidelobes at all would be only 70 db for this aperture size and this wavelength Fig. 2 shows the typical structure of the main- and sidelobe pattern.

Considerable experience has now been accumulated with the Kennedy Spincasting technique for generating surfaces of this sort. This process forms a "natural" paraboloid by centrifugally spinning the liquid constituents of a plastic material until they fully react and "take cast." Then the plastic surface is metallized or mirrorized, depending upon wavelength of the radiant energy to be handled—in this case, molten-spray-metallized for use with radio wavelengths in the millimeter range.

Of basic importance to the success of the Spincasting technique is the selection of optimum Spincast materials and the maintenance of control in their processing. Because of practical considerations, the coating is ordinarily $\frac{1}{4}$- to $\frac{3}{8}$-in thick. In the liquid state the viscosity must be low and/or "pot life" long. All synthetic plastics tend to have a coefficient of thermal expansion many times that of the metal support; it is important that the materials selected have enough resilience to prevent cracking and "bimetallic" warp of the precision surface. The 28-ft reflector described in this letter was Spuncast with a relatively new plastic which has shown excellent test performance. Environmental tests that have been made by Kennedy on the flexible Spuncast base and surface coatings show gratifying resistance to influences of Weatherometer exposure, water, chemicals and temperature extremes.

Fig. 1 shows the new reflector positioned by a manually controlled elevation-azimuth steerable mount. The machined appearance of the reflector is actually due to the method of applying the zinc spray conductive coating. Aperture holes contain two tracking telescopes. Water drain holes are located near the vertex.

Fig. 1 also shows part of the aluminum-plate-girder tangential-beam construction developed to provide support for the precision reflector. This framework attaches to the mount-adaptor at six hexagonally related points. Half-foot-deep honeycomb panels of 8-ft triangular form are supported from the girder frame, using threaded pillars attaching at corners and midway along each side of the honeycomb panels. The spincoating adheres directly to these panels.

Obviously, reflectors of this accuracy require a very rigid support to maintain the precision tolerances of the reflector surface and to resist pattern distortions caused by the pull of gravity and the thrust of wind pressures. No such distortions were noticed during the pattern tests, but it remains to attempt quantitative evaluation. Sunlight striking one side of the reflector does show some influence as was expected, and most of the measurements have been made after sunset to avoid such effects.

The new antenna is being used by Lincoln Laboratory in system-testing components and techniques for radar and space communications at 8-mm wavelength. It is expected that it will also be tested at even shorter wavelengths at some future time. Kennedy is pursuing development work and current negotiations applying to still shorter wavelengths of interest in radio astronomy and space research.

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* Received February 9, 1962; revised manuscript received February 20, 1962.

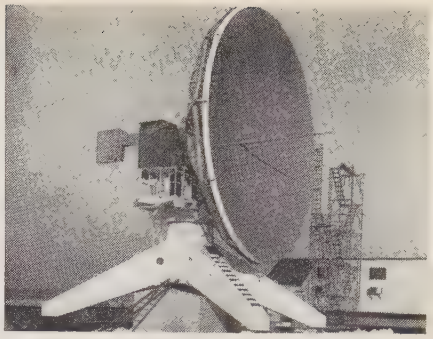

Fig. 1.

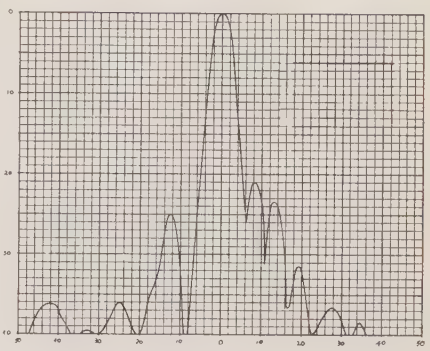

Fig. 2—28-ft. spuncast reflector. 35,300 Mc. Azimuth pattern. 4.4 minute beamwidth. 67.4-db gain.

Continuous Operation of a Parametric Amplifier for Radio Astronomy*

A degenerate parametric amplifier constructed at the National Research Council has been in operation since April, 1961, as a preamplifier with the compound interferometer used for solar noise studies.[1]

The amplifier was designed and built to improve the signal-to-noise performance of the interferometer in strip-scanning the sun. It has a bandwidth of 6 Mc, a double sideband gain of 20 db, and a noise temperature of 200°K, and is used ahead of a TWT amplifier and superheterodyne receiver with an over-all bandwidth of 0.5 Mc at 2.830 Gc. In order to compensate for shift in antenna

* Received March 9, 1962.

[1] R. F. Clark and A. E. Covington, "A parametric amplifier for the 10.7-cm compound interferometer," *J. Roy. Astron. Soc. of Canada*, vol. 56; March, 1962.

pattern of the interferometer due to changing temperature, it is necessary to tune the receiver by changing the local oscillator frequency by a small amount around 2.800 Gc. Since the parametric amplifier is operated in the degenerate mode it is essential that its pass band track accurately with that of the receiver. This is accomplished by phase-locking the pump klystron to a frequency which is equal to twice the sum of the local oscillator frequency (2.8 Gc) and the receiver intermediate frequency (30 Mc). The pump frequency is controlled by mixing the pump and local oscillator signals, amplifying the resultant difference-frequency signal, comparing it in a 60-Mc phase discriminator with a crystal-controlled reference signal which is twice the intermediate frequency. The dc error signal from the discriminator then controls the klystron reflector voltage.

A frequency pull-in range of ± 0.5 Mc, necessitated by transients associated with the local oscillator, was obtained with a simple transformer-coupled phase discriminator. The dc output of the two semiconductor diodes in the discriminator was connected in series between the pump klystron reflector and a conventional klystron power supply. The receiver is tuned once daily to a frequency corresponding to the temperature of the antenna. The pump klystron frequency is manually adjusted for phase-lock at this time, if the frequency change exceeds the pull-in range of the pump frequency control.

The gain of the amplifier has been stabilized with respect to variations in pump klystron output level, through the use of a pump amplitude control (see Fig. 1). The amplitude-sensing element for the control is a diode of the same type as the amplifier diode. It is coupled to the pump waveguide by a directional coupler placed immediately before the amplifier cavity. The output of the sensing diode is compared with a dc reference, the difference voltage being amplified to control a coaxial diode switch which acts as an attenuator in the pump waveguide line. Isolators were placed before and following the switch because it is reflective. A low-pass filter was also used to eliminate harmonics of the pump frequency. An amplifier gain variation of less than one per cent over a period of several hours was measured with the above circuit.

Isolation of 50 db was provided at the input and output of the amplifier so that it could be inserted easily in front of the low-noise traveling-wave tube used as a pre-amplifier in the interferometer. For the first two weeks the parametric amplifier was used on alternate days in order to evaluate its performance. Shown in Fig. 2 is a comparison of the drift-curve obtained on April 20, 1961, with the low-noise TWT receiver, and that obtained on April 21, when the parametric amplifier was placed between the traveling-wave tube and the antenna. On both days the sensitivity of the receiver was adjusted to give approximately the same deflection. The central raised portion of the chart represents the solar disk as scanned by the 1.2 minutes of arc fan-shaped beam (the horizontal bar shows the 32-minute extent of the photospheric disk); the superimposed peaks on the central region are due to sunspots on the sun, and their displacement from one day to the next is due to rotation of the sun. The photograph shows that a decrease in noise fluctuations has occurred and that the general quality of the drift-curves has improved.

The amplifier has since been operated continuously, except during two power supply tube failures—one in June, and one in November. The only adjustment made to the parametric amplifier is the daily locking of the pump klystron frequency to that of the local oscillator. However, the sensitivity of the entire receiver is measured daily and, from time to time, an attenuator following the traveling-wave tube is adjusted to compensate for the long-term changes in the over-all performance of the receiver.

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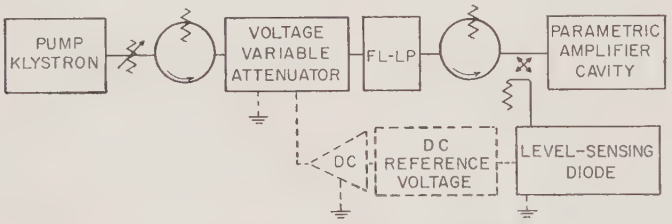
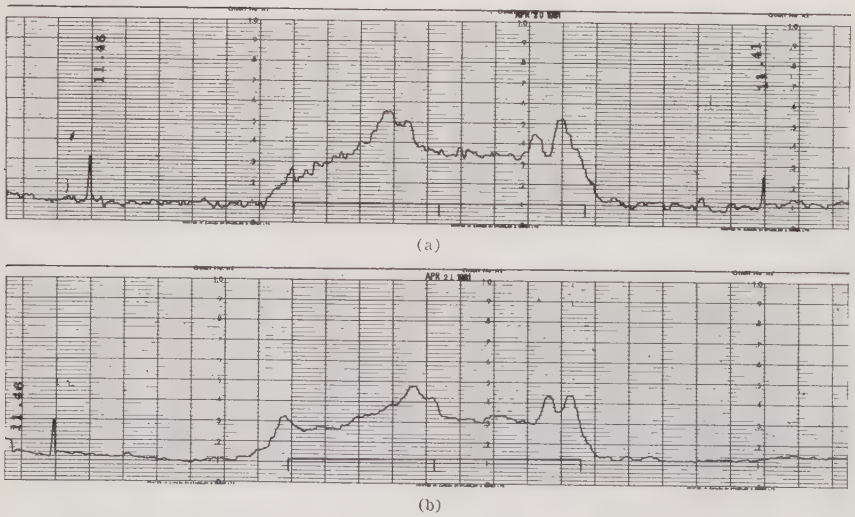


Fig. 1—Amplitude control loop for the pump klystron.



(a)

(b)

Fig. 2—Strip-scans of the disk taken on consecutive days with different receivers. (a) Solar scan taken with parametric amplifier between TWT and antenna. (b) Solar scan taken with low-noise TWT (RCA Type 6861).

Extent of photospheric disk (32 minutes of arc) is given by bar under the curve at same level as sky background. Unwanted fluctuations in signal strength appear as small irregularities in curves. Flat portion of scan curve represents level of undisturbed solar disk; superimposed peaks represent radio-emissive regions associated with sunspot activity.

Optical Maser Characteristics $BaF_2:U^{3+}$ *

The observation of optical maser action in trivalent uranium incorporated into barium fluoride has been reported previously.[1,2] In this note we report on some of the measured characteristics of this maser.

The output frequency is 3912 cm^{-1} (2.556 microns). It was determined with the use of a Perkin-Elmer 210 grating monochromator in a manner similar to that described in the following note. The fluorescence of $BaF_2:U^{3+}$ was studied by Galkin and Feofilov[3] who, however, did not find any line at 2.556μ. One possible cause for this difference is that at the relatively high temperature (123°K) at which their measurement was performed the 2.556μ fluorescence is not sufficiently well resolved.

The threshold measurements were taken with the crystal placed at the center of a FT 524 flash lamp. (A procedure which in spite of some obvious limitations seems to gain acceptance for threshold comparisons). The threshold energy input at 20°K was 12 joules. No maser action was observed at liquid nitrogen temperature (77°K) with energy inputs of up to 2000 joules.

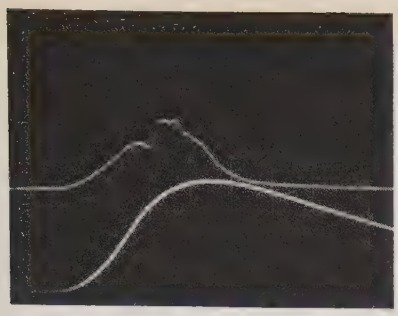
Absorption measurements at 20°K showed lines at 4505 cm^{-1} (2.220μ), 4376 cm^{-1} (2.285μ), 4198 cm^{-1} (2.382μ), 4139 cm^{-1} (2.417μ), 3882 cm^{-1} (2.576μ) and at 4019

* Received April 11, 1962.

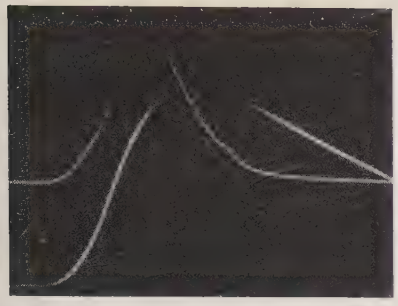
[1] P. A. Miles, private communication.

[2] H. A. Bostick and J. R. O'Connor, "Infrared oscillations from $CaF_2:U^{+3}$ and $BaF_2:U^{+3}$ Masers," Proc. IRE (*Correspondence*), vol. 50, pp. 219–220; February, 1962.

[3] L. N. Galkin and P. P. Feofilov, *Optics and Spectroscopy*, vol. 1, p. 492; 1959.



(a)



(b)

Fig. 1—(a) *Upper trace:* The 2.556μ maser emission from the lightly silvered face as detected by a PbSe photoconductive cell. *Lower trace:* Output voltage across the *RC* network ($RC = 150 \times 10^{-6}$ sec) fed by a phototube monitoring the flash pump light of the FT 524. Sweep rate (both traces) 20μsec per division. Energy input (to FT 524) 15 joules. (b) Same as (a) except that energy input is 25 joules.

cm^{-1} (2.488μ). These are attributed to transitions from the ground state (belonging to the $^4I_{9/2}$ multiplet) to levels belonging to the $^4I_{11/2}$ group at 4019, 3882, 4139, 4198, 4376 and 4505 cm^{-1} from the ground state. The temperature dependence of the threshold is most consistent with the assignment of the maser, 3912 cm^{-1}, line to a transition from the metastable level at 4019 cm^{-1} to a terminal level at 107 ($=4019-3912$) cm^{-1} from the ground state. We have not ruled out completely the possibility that the metastable level is at 4139 cm^{-1}.

The maser action is stimulated mostly by radiation at $\lambda > 1.0\mu$. Elimination of visible radiation causes an increase of the pumping energy by ≈ 10 per cent. The absorption bands responsible for the maser action are at 1.1μ and at 1.5μ.

The lifetime of the metastable level was measured by the analog method which is described in detail in Yariv, *et al.*[4] This method consists of observing simultaneously, with the aid of a double-beam oscilloscope, the detected maser output and the output voltage across an *RC* network which is current-fed by a phototube monitoring the flash light. When the *RC* product is made equal to the lifetime τ of the metastable state, the voltage across the *RC* network at the onset of maser oscillation is always the same regardless of the total energy input to the lamp. The lifetime τ found in this manner was 150μsec $\pm$ 10μsec at 20°K. Fig. 1 shows the oscilloscope pictures taken with $RC = \tau$.

[4] A. Yariv, S. P. S. Porto and K. Nassau, *J. Appl. Phys.* (Tentatively scheduled for publication in July, 1962.)

The proximity of the output wavelength at 2.556μ to that of the $CaF_2:U^{3+}$ maser at 2.613μ and the superior maser characteristics of the latter[5] diminish to a large extent the practical importance of this maser except for special applications where the wavelength difference may become important.

The crystal used in the experiment was obtained from W. A. Hargreaves of Optovac Incorporated. We are indebted to Miss D. M. Dodd for the absorption measurements and to A. L. Albert, L. E. Cheesman, J. M. Dziedzic and D. H. Olson for competent experimental assistance.

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[5] G. D. Boyd, R. J. Collins, S. P. S. Porto, A. Yariv and W. A. Hargreaves, *Phys. Rev. Letts.*, vol. 8, p. 269; 1962.

Excitation, Relaxation and Optical Maser Action at 2.407 Microns in $SrF_2:U^{3+}$ *

The observation of fluorescence in the 2.14–2.46 micron(μ) region from trivalent uranium incorporated into strontium fluoride was first reported by Galkin and Feofilov.[1] We have observed stimulated maser emission at 2.407μ from this material and have determined the pertinent energy levels, the relaxation times and the excitation conditions.

The experimental set-up was described in detail in another paper[2] and consisted of a dewar with the crystal supported within its lower narrow section. The narrow section of the dewar was surrounded by a helical FT 524 flash lamp providing the pulsed pumping. The emitted infrared radiation from the lightly silvered side of the crystal was trapped in a quartz "light-pipe" and detected by a photoconductive PbSe cell with a time resolution of 5μsec.

The wavelength of the maser emission was 2.407μ (4155 cm^{-1}) and was determined by directing the maser output beam into a Perkin-Elmer 210 grating monochromator and placing a PbSe detector at the output slit. It is of interest to note that the difference between the output wavelength of the $CaF_2:U^{3+}$ maser at 2.613μ and that of $SrF_2:CaF_2$ at 2.407 does not reflect the change in the strength of the crystalline electric field between the two surroundings[1] but is due to the fact that the maser transition connects different levels in the two materials. The reason for this difference is not understood.

The spectral region most efficient in exciting the maser emission was determined by placing the FT 524 alongside the dewar opposite the crystal and inserting glass (Corning) filters in the path of the pumping light. In this manner we were able to ascertain that approximately 60 per cent of the useful excitation is due to absorption in the 1–1.3μ region with the rest being due to absorption by the intense ($f \approx 10^{-3}$) band spanning the 4000–6000 Å region. The first region contains narrow absorption bands, with $\Delta\nu$ ranging from 10 to 20 cm^{-1}, at 1.078, 1.096, 1.17, 1.183, 1.204 and 1.213 microns which belong to the $^4I_{13/2}$ manifold and whose oscillator strengths range from $f \approx 0.5 \times 10^{-6}$ to $f \approx 2 \times 10^{-5}$.

Paramagnetic resonance investigation at 23 kMc revealed that the emission is due to trivalent uranium ions in sites of fourfold symmetry first described by Bleaney, *et al.*[3] The trigonal sites whose presence in $CaF_2:U^{4}$ is always associated with poor maser performance[4,5] were also present.

Galkin and Feofilov[1] have measured the fluorescence of $SrF_2:U^{3+}$ at 300°K and at 123°K and reported lines at 4673 cm^{-1} (2.14μ), 4545 cm^{-1} (2.20μ), 4464 cm^{-1} (2.24μ), 4348 cm^{-1} (2.30μ), 4155 cm^{-1} (2.406μ) and at 4065 cm^{-1} (2.46μ). The lines at 4545, 4155 and at 4065 cm^{-1} are the strongest at 123°K and can be assigned to transitions from the lowest lying level of the $^4I_{11/2}$ manifold or from levels within ≈ 50 cm^{-1} from it, to levels of the $^4I_{9/2}$ group. We have observed in absorption transitions at 4617 cm^{-1} (2.166μ), 4518 cm^{-1} (2.213μ), 4509 cm^{-1} (2.218μ), 4494 cm^{-1} (2.225μ) and at 4489 cm^{-1} (2.228). The intensity of these lines remains comparable at 20°K to that at 77°K which leads us to attribute them to transitions from the ground state to levels of the $^4I_{11/2}$ manifold at 4617, 4518, 4509, 4494 and 4489 cm^{-1} from the ground state. The observed maser emission at 4155 cm^{-1} is thus assigned to a transition from the lowest $^4I_{11/2}$ level at 4489 cm^{-1} to a level, belonging to $^4I_{9/2}$, 334 cm^{-1} from the ground state. We have accounted for five levels of the $^4I_{11/2}$ manifold. The expected number of levels for $J = 11/2$ in a field of fourfold symmetry is six. The positions of the absorption bands and energy levels pertinent to the (simplified) description of the maser action are shown in Fig. 1.

The lifetime τ of the metastable level was measured by the analog method as described by Yariv, *et al.*,[2] and in the preceding note. The measurement was performed at 20°K, 77°K and at 90°K and yielded $\tau_{20°} = 110\mu\text{sec} \pm 10\mu\text{sec}$, $\tau_{77°} = 80\mu\text{sec} \pm 10\mu\text{sec}$, $\tau_{90°} = 60\mu\text{sec} \pm 10\mu\text{sec}$. Nonradiative relaxation is thus seen to set in between 20°K and 77°K.

The threshold energy input was measured at 300°K, 90°K, 77°K and at 20°K. The sample crystal had a 0.1 mole-per cent concentration. At 300°K we could not obtain maser emission with energy inputs to FT 524 flash lamp of up to 2000 joules. The threshold energy inputs at 90°K, 77°K and

* Received April 11, 1962.

[1] L. N. Galkin and P. P. Feofilov, *Optics and Spectroscopy*, vol. 1, p. 492; 1959.

[2] A. Yariv, S. P. S. Porto and K. Nassau, *J. Appl. Phys.* (Tentatively scheduled for publication in July, 1962).

[3] B. Bleaney, P. M., Lewellyn and D. A. Jones, *Proc. Phys. Soc.*, vol. B69, p. 858; 1956.

[4] S. P. S. Porto and A. Yariv, *J. Appl. Phys.* (to be published.)

[5] A. Yariv, "Paramagnetic Resonance of Trigonal and Non-Axial Sites of U^4 in CaF_2," to be published.

20°K were 38, 32 and 8 joules, respectively. The fourfold reduction in threshold between 77°K and 20°K may be due to narrowing of the fluorescence linewidth and/or to a more complete depopulation of the terminal level. The separation of the terminal level from the ground state, 334 cm^{-1}, is such that at temperatures near ≈ 50°K the population of the terminal state becomes comparable to the critical (threshold) population inversion with a concomitant increase in threshold. The threshold at 20°K is three times higher than that of our best $CaF_2:U^{3+}$ crystals which have operated as continuous masers,[6] so that $SrF_2:U^{3+}$ is a promising candidate for continuous operation.

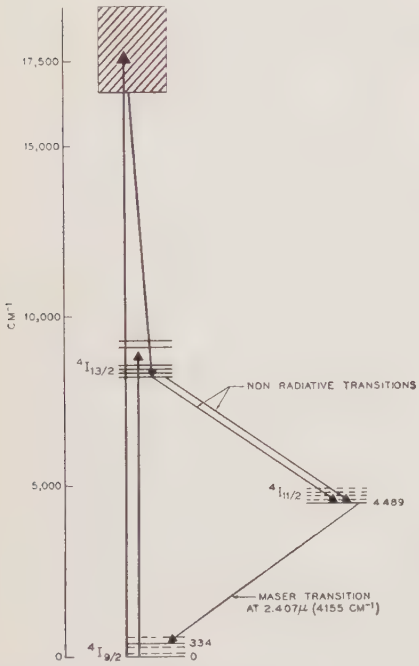

Fig. 1—Energy levels partaking in maser action in $SrF_2:U^{3+}$ maser.

The output frequency of the $SrF_2:U^{3+}$ maser at 4155 cm^{-1} corresponds to the tail edge of the water vapor absorption band which is centered at 3700 cm^{-1}.[7] This fact may become very important when long distance propagation through real or artificial atmospheres is considered.

The crystal used in this experiment was obtained from W. A. Hargreaves of Optovac Incorporated.

It is a pleasure to acknowledge the cooperation of Miss D. M. Dodd who performed the optical absorption measurement and that of A. L. Albert for crystal preparation, J. M. Dziedzic for assistance in the paramagentic resonance study and L. E. Cheesman and D. H. Olson for their versatile experimental assistance.

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[6] G. D. Boyd, R. J. Collins, S. P. S. Porto, A. Yariv and W. A. Hargreaves, *Phys. Rev. Letts.*, vol. 8, p. 269; 1962.
[7] D. E. Burch, J. W. Howard and D. Williams, *J. Opt. Soc. Am.*, vol. 46, p. 452; 1956.

Correction to "Doppler Studies of the Ionosphere with Vertical Incidence"*

The author of the above correspondence[1] is indebted to R. Silberstein for pointing out the following errors.

In (6) p. 94, the letter T should be used for layer thickness. For a *double* traverse of a layer (6) should read

$$\delta f = \frac{T}{c}\frac{k}{f}\frac{dN}{dt}.$$

Also, when both height of reflection and electron content change,

$$\delta f = Af\frac{dh}{dt} + \frac{B}{f}\frac{d\left(\int N dh\right)}{dt},$$

where

$$A = -\frac{2}{c}, \qquad B = \frac{k}{c}$$

which can be solved for

$$\frac{dh}{dt} \text{ and } d\left(\int N dh\right)/dt$$

using δf measurements on two frequencies. Note that $\int N dh$ represents the total electron content in a vertical cylinder of unit cross-sectional area.

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* Received January 30, 1962.
[1] Proc. IRE, vol. 50, p. 94; January, 1962.

Comments on "Noise in Photoelectric Mixing"*

Signal-to-noise ratios of photoelectric heterodyne and homodyne converters have recently been discussed by Oliver.[1] Here we intend to discuss further the similarities and differences between these two types of converter, and to point out the connection between Oliver's treatment and the principle of complementarity.

When amplifier-noise theory is carried to the point of including fluctuations that are due to single quanta, it is usually important to consider the principle of complementarity, a specifically quantum-mechanical constraint. This principle shows, in particular, that one can never determine the phase and energy in an electromagnetic wave with a precision greater than that allowed by the relation[2-4]

$$\Delta\phi\Delta n \geq \tfrac{1}{2},$$

where $\Delta\phi$ is the rms uncertainty in the phase of the wave, and Δn the rms uncertainty in the number of quanta which it contains. Oliver's discussion[1] concentrates attention on fluctuation in the number of quanta, and hence does not study several important points concerning the phase fluctuations.

Consider a photoelectric detector in which an incoming light signal of frequency ω_s is mixed with a local oscillator of frequency ω_o. As in Oliver's equation (5), the signal current is

$$i_s = \frac{q}{h\nu} A_o A_s \cos\left[(\omega_s - \omega_o)t + \phi\right], \qquad (1)$$

where q is the electron charge, $h\nu$ the quantum energy, A_o the local oscillator amplitude, and A_s the signal amplitude. Here we have introduced ϕ as the phase angle that may exist between the two waves and assumed, as we shall hereafter, that the quantum efficiency of the photocell is unity. The mean-square signal current, from (1), is

$$\overline{i_s^2} = \left(\frac{q}{h\nu}\right)^2 A_o^2 A_s^2 \overline{\cos^2\left[(\omega_o - \omega_s)t + \phi\right]}. \qquad (2)$$

The mean-square shot-noise[1] is

$$\overline{i_n^2} = \frac{q^2}{h\nu} B A_o^2, \qquad (3)$$

where B is the bandwidth, and the local-oscillator power is assumed to be very large compared with the signal power, $P_s = \frac{1}{2}A_s^2$. For a heterodyne mixer, with a frequency difference $\omega_s - \omega_o$ which is much larger than the bandwidth B, the $\cos^2$ factor in (2) averages to $\frac{1}{2}$. For the SNR[1] we have

$$\frac{S}{N} = \frac{\overline{P_s}}{h\nu B}. \qquad (4)$$

As Oliver notes, this is exactly the same result as that obtained for the ideal maser. The noise performances of the ideal heterodyne mixer and the ideal maser at high gain are identical. To either amplifier one may connect a detector that detects simultaneously the phase and the amplitude of the output. The detector does not affect the SNR if the power level at the output is sufficiently high (high gain!). One can show[2,4] that the noise introduced in the ideal maser and heterodyne mixer is such as to cause an uncertainty $\Delta\phi$ in phase of the output with respect to that at the input, $\Delta\phi = 1/(2\sqrt{n})$, where n is the number of photons in the incoming signal. Similarly, one can show that the prediction of the incoming photon number from the measured number of photons at the maser (or heterodyne mixer) output suffers an uncertainty $\Delta n = \sqrt{n}$. Thus, the ideal maser and the ideal heterodyne mixer permit a measurement of phase and amplitude

* Received March 26, 1962. This work was supported in part by the U. S. Army Signal Corps, the AF Office of Scientific Research, and the Office of Naval Research.
[1] B. M. Oliver, "Signal-to-noise ratios in photoelectric mixing," Proc. IRE (*Correspondence*), vol. 49, pp. 1960–1961; December, 1961.

[2] R. Serber and C. H. Townes, "Limits on electromagnetic amplification due to complementarity," in "Quantum Electronics," C. H. Townes, Ed., Columbia University Press, New York, N. Y., p. 233; 1960.
[3] H. Friedburg, "General amplifier noise limit," in "Quantum Electronics," *op. cit.*, p. 228.
[4] H. A. Haus and J. A. Mullen, "Quantum Noise in Linear Amplifiers," unpublished.

within uncertainties that satisfy the uncertainty relation with an equality sign, $\Delta n \Delta\phi = \frac{1}{2}$.

For homodyne detection $\omega_o = \omega_s$, and the mean-square value of the signal current, from (1), is

$$\overline{i_s^2} = \left(\frac{q}{h\nu}\right)^2 A_o^2 A_s^2 \overline{\cos^2\phi}. \tag{5}$$

This gives for the SNR

$$\frac{S}{N} = \frac{A_s^2 \cos^2\phi}{h\nu B} = \frac{\overline{P}_s}{\left(\frac{h\nu}{2}\right)B}\,\overline{\cos^2\phi} \tag{6}$$

where $\overline{P}_s = A_s^2/2$ is the signal power. This expression is the same as that given by Oliver, except for what might seem like a trivial generalization, the inclusion of an arbitrary phase angle, which he assumed to be zero.

Consider now the nature of the incoming signal. If we have no prior knowledge about it, we cannot know ϕ, and hence must accept a random value for the relative phase of the signal and local oscillator. This gives $\overline{\cos^2\phi} = \frac{1}{2}$, and

$$\frac{S}{N} = \frac{P_s}{h\nu B}. \tag{7}$$

This is the same answer as that for the heterodyne mixer. But suppose the receiving engineer has some prior knowledge of the phase. The signal might, for example, be transmitted from a powerful oscillator of extreme phase stability. The transmitter phase could then be chosen by prior agreement. Or the receiving engineer, knowing that the transmitter phase is kept constant, might measure the *average* received phase by introducing a small fraction of the incoming power into an amplifier of bandwidth much narrower than that of the homodyne. Allowing for a sufficient length of time for the phase measurement he can perform it without undue weakening of the input signal to the homodyne and correspondingly without important change in the input SNR. In this case he might assume he is detecting the incoming wave, resulting from the transmitted signal after the radiative (inverse-square law) attenuation, by arranging his local oscillator so that $\phi = 0$, in which case $\cos^2 = \phi = 1$, and

$$\frac{S}{N} = \frac{P_s}{\frac{h\nu B}{2}}. \tag{8}$$

This prior knowledge of phase constancy has apparently been assumed in Oliver's discussion, and our (8) is the same result as his expression (10).

It should not be surprising that the SNR in (8) is twice as good as that given by an ideal amplifier such as a maser because the receiving engineer, in this case, is measuring a different property of the incoming wave. He measures only that part of the wave for which $\phi = 0$. In fact he does not know that the incoming wave is precisely in this phase, and one can show, as will be indicated below, that it cannot be. The improved SNR allows him to measure the photon number with an accuracy twice that of the ideal maser. He has lost, however, a good part of the knowledge of phase of the incoming wave (at the receiver input), a phase whose average is equal to the transmitter phase but which is still subject to rapid fluctuations. In order to make good use of the homodyne principle he need know only that the phase of the incoming wave deviates from the fixed phase of his local oscillator by $\Delta\phi \ll 1$. But this limiting range can be much wider than that imposed by the uncertainty principle, which imposes the lower bound on the uncertainty of simultaneous measurement of phase and amplitude, $\Delta\phi \geq 1/\sqrt{\bar{n}}$. Here we are assuming that n is considerably larger than unity, which is required in order for phase to have any clear meaning in the quantum-mechanical case. If n approaches unity, the SNR becomes poorer than that given by expression (8).

If the receiving engineer were willing to sacrifice all knowledge about phase, he could perform (in principle) amplitude measurements with accuracies much greater than those of the homodyne receiver. One must only satisfy the relation $\Delta\phi\Delta n \geq 1/2$, and if there is no information about phase, so that $\Delta\phi$ becomes very large, Δn may approach zero.[5] Such is the case for a perfect photodetector with no local oscillator, which, in principle, counts individual photons with no noise background at all, but gives no information about phase.

One might perhaps suggest utilizing the improved SNR of the homodyne given by (6) for an incoming wave of unknown phase by making a separate determination of the phase of the wave just before homodyne detection. Then a rather exact phase is known and the local oscillator phase can be chosen accordingly. This would make the receiver independent of any prior knowledge of phase. But any such attempt to measure phase could only result in introducing noise fluctuations into the signal. Since the principle of complementarity again requires $\Delta\phi\Delta n \geq 1/2$, a decrease in the uncertainty $\Delta\phi$ will result in an increase in energy fluctuations Δn in such a way that the total SNR after phase determination and photoelectric conversion cannot be improved upon over that which was obtainable without the phase measurement.

To indicate why the receiving engineer cannot be certain of the phase of the wave when it reaches him, even if it is transmitted by a stable oscillator of known phase, consider a weak signal that results from the attenuation of a powerful transmitted wave of fixed amplitude and phase. The attenuation is usually due to the radiative inverse-square law decrease (with distance from the antenna) of the electromagnetic power density. Classically speaking, one may be inclined to think that the signal at the receiver has a definite power and phase determined by the transmission path. But, according to the principle of complementarity, $\Delta\phi\Delta n \geq 1/2$, and the phase cannot be very exactly known ($\Delta\phi \to 0$) without the energy fluctuations, Δn, becoming very large. In fact, after any normally large attenuation, the mean-square fluctuations in the average phase[6] are given by $\Delta\phi = 1/(2\sqrt{n})$ and those in number of quanta by $\sqrt{n}$, where n is the average number of photons arriving at the receiver within any specified time.

We have benefitted from discussions with Drs. J. P. Gordon and B. M. Oliver.

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[5] The time of observation (inverse bandwidth) is assumed to be sufficiently long that the uncertainty in n resulting from the noninfinite observation time is negligibly small compared with the uncertainties discussed here.

[6] Serber and Townes, *op. cit.*; see in particular (71) and (73).

Author's Reply[7]

Haus and Townes have made some interesting and pertinent comments on my earlier discussion of photoelectric mixing.[1] From these and from further correspondence with Haus and with J. P. Gordon of Bell Labs. it appears that it is indeed possible to construct a linear *amplitude* or a linear *phase* detector having an equivalent input noise power spectral density

$$\psi(\nu) = \frac{h\nu}{\exp\left(\frac{h\nu}{kT}\right) - 1} + \frac{h\nu}{2} \tag{1'}$$

rather than the density

$$\psi(\nu) = \frac{h\nu}{\exp\left(\frac{h\nu}{kT}\right) - 1} + h\nu \tag{2'}$$

which characterizes an ideal linear amplifier. The following discussion of a particular system may help to clarify this matter

Fig. 1 shows a receiver capable of homodyne detection with phase lock, and also of simultaneous in-phase and quadrature detection. Before entering the balanced homodyne mixer on the right, a fraction (ϵ) of the

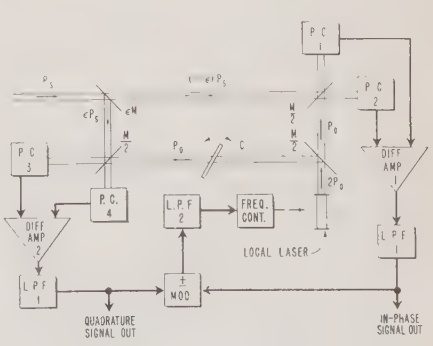

Fig. 1

[7] Received April 27, 1962.

received signal power (P_s) is diverted by a partially reflecting mirror (ϵM) into an auxilliary balanced mixer. The relative optical path lengths from the common local laser are adjusted (by rotating the compensating plate, C) so that when the phase angle between the signal and local oscillator is zero at the mixer on the right, it is $\pm\pi/2$ at the auxilliary mixer. With these phase relations the right-hand mixer responds to in-phase (amplitude) variations of the signal and the auxilliary mixer to quadrature (phase) variations. For the moment consider P_s to be a CW signal and assume differential amplifier 2 to be connected directly to low-pass filter 2. If the bandwidth of this filter is much less than ϵB, where B is the bandwidth of the low-pass signal filters (LPF1), a relatively noise-free control signal will be produced which can vary the local laser frequency by any suitable means. We thus have a closed-loop phase-lock system whose response time is inversely proportional to ϵB. Assuming sufficient frequency stability in the signal and local laser we can let $\epsilon \to 0$ thus producing negligible degradation of the SNR at the in-phase detector. We are taking advantage of the fact that the information rate necessary to maintain phase lock can be made negligible compared with the signaling rate, and hence a negligible fraction of the received power need be diverted for this purpose.

If P_s is a carrier suppressed AM signal (for example a binary channel using positive and negative pulses) we must reverse the phase in the feedback loop as the signal phase reverses, in order to maintain negative feedback. This is the function of the $\pm$ modulator. The system will now lock in one of two possible states so there is a polarity ambiguity in the output which, if important, can be corrected once and for all at the start of each transmission. This receiver, without prior phase knowledge, gives the noise performance corresponding to (1).

Now assume that the signal applied to this receiver is first amplified by an ideal high-gain maser. From (2) the signal applied to the receiver will now contain a noise power density of $h\nu$ w/cps referred to the input, while the receiver noise will be negligible by comparison. In developing a signal of bandwidth B, the in-phase homodyne mixer responds to half the noise power in a bandwidth $2B$ centered at ν. Thus the output noise power is now $h\nu B$, referred to the input, corresponding to a spectral density $h\nu$, or twice as much as without the preamplifier.

To see why this is so, let us examine the NSRs in both outputs of the receiver of Fig. 1 without the preamplifier. From the discussion in the original paper[1] this ratio in the in-phase channel is obviously (assuming $\eta = 1$):

$$\frac{\overline{i_n^2}}{i_s^2} = \frac{h\nu B}{2(1-\epsilon)P_s}. \tag{3}$$

If $W_s = P_s/2B$ is the signal energy per elementary pulse (or Nyquist interval), then

$$\frac{\overline{i_n^2}}{i_s^2} = \frac{h\nu}{4(1-\epsilon)W_s} = \frac{1}{4(1-\epsilon)\bar{n}} \tag{4}$$

where $\bar{n} = W_s/h\nu$ is the photon expectation per pulse. Now

$$\frac{\overline{i_n^2}}{i_s^2} = \frac{\overline{\delta_n^2}}{(\bar{n})^2} \tag{5}$$

where $\overline{\delta n^2} \equiv (\Delta n)^2$ is the mean-square fluctuation in photon count. Combining (4) and (5) we find

$$\overline{\delta_n^2} = \frac{\bar{n}}{4(1-\epsilon)}. \tag{6}$$

In the quadrature channel we find similarly that the ratio of mean-square noise current to the square of the signal current, i_s', produced by unit phase deviation of the signal is

$$\frac{\overline{i_n^2}}{i_s'^2} = \frac{1}{4\epsilon\bar{n}} \tag{7}$$

and this ratio is the apparent mean-square phase perturbation $\delta\phi^2 \equiv (\Delta\phi)^2$, due to noise. Thus from (6) and (7)

$$(\Delta n \Delta\phi)^2 = \frac{1}{16\epsilon(1-\epsilon)}. \tag{8}$$

The minimum value of this expression occurs when $\epsilon = \frac{1}{2}$ and we then have $\Delta n \Delta\phi = \frac{1}{2}$ in agreement with the principle of complementarity. Both output signals now contain a noise of $h\nu$ w/cps referred to the input. The two signals jointly completely describe the input wave modulation and could be used to reconstruct it aside from the added noise. Thus this system with $\epsilon = \frac{1}{2}$ is directly comparable to the ideal amplifier or heterodyne mixer and gives the same noise performance.

It is evident that by making $\epsilon = 1$ we could detect quadrature modulation of the signal with a noise of $h\nu/2$ referred to the input. Thus we can detect *either* amplitude modulation *or* phase modulation with a noise performance corresponding to (1). If we wish to do *both* we are reduced to the performance given by (2), and can then equally well use an ideal maser amplifier, a heterodyne mixer, or the double homodyne system with $\epsilon = \frac{1}{2}$. Further, unless we wish to do both, the maser preamplifier should not be used.

B. M. Oliver
Hewlett-Packard Co.
Palo Alto, Calif.

* Received, April 23, 1962.

[1] See "National Standards of Time and Frequency in the United States," Proc. IRE, vol. 48, pp. 105–106; January, 1960.

WWV and WWVH Standard Frequency and Time Transmissions*

The frequencies of the National Bureau of Standards radio stations WWV and WWVH are kept in agreement with respect to each other and have been maintained as constant as possible with respect to an improved United States Frequency Standard (USFS) since December 1, 1957.[1] The corrections reported here were arrived at by means of improved measurement methods based on NBS LF and VLF transmissions. The values given are 5-day running averages of the daily 24 hour values for the period beginning at 1800 UT of each day listed.

The WWV and WWVH time signals are also kept in agreement with each other. Since they are locked to the frequency of the transmissions, a continuous departure from UT2 may occur. Corrections are determined and published by the U. S. Naval Observatory. The broadcast signals are maintained in close agreement with UT2 by properly offsetting the broadcast frequency from the USFS at the beginning of each year when necessary. This new system was commenced on January 1, 1960.

WWV Frequency
With Respect to U. S. Frequency Standard

1962	February Parts in 10^{10}†	March Parts in 10^{10}†
1	−130.0	−130.5‡
2	−130.1	−131.4
3	−130.2	−131.5
4	−130.2	−131.6
5	−130.2	−131.7
6	−130.2	—‖
7	−130.1	−132.2‡
8	−130.2	−131.8‡
9	−130.1	−131.0‡
10	−130.1	−130.3
11	−130.0	−130.6‡
12	−130.1	−129.7
13	−130.0	−130.0‡
14	−130.0	−130.9‡
15	−130.0	−130.2
16	−129.9	−130.2
17	−129.9	−130.1
18	−129.8	−130.0
19	−129.9	−130.0
20	−130.0	−130.0
21	−130.3	−130.0
22	−130.5	−130.0
23	−130.8	−130.0
24	−130.8	−130.0
25	−130.8	−129.9
26	−130.6	−129.8
27	−130.5	−129.7
28	−130.3	−129.7
29		−129.7
30		−129.8
31		−129.8

† A minus sign indicates that the broadcast frequency was below nominal. The uncertainty associated with these values is $\pm 5 \times 10^{-11}$.

‡ WWV frequency was adjusted as follows:

March 1, -0.7×10^{-10}
March 7, $+0.7 \times 10^{-10}$
March 8, $+1.4 \times 10^{-10}$
March 9, $+1.0 \times 10^{-10}$
March 11, $+1.1 \times 10^{-10}$
March 13, -0.8×10^{-10}
March 14, $+0.8 \times 10^{-10}$

‖ No transmission, power outage, 0733-0025 UT, March 6–7, 1962.

Subsequent changes were as follows:

Frequency Offset, with reference to the USFS

January 1, 1960 −150 parts in 10^{10}
January 1, 1962 −130 parts in 10^{10}

Time Adjustments, with reference to the Time Scale UT2

December 16, 1959, retardation, 20 Milliseconds
January 1, 1961, retardation, 5 Milliseconds
August 1, 1961, advancement, 50 Milliseconds

Adjustments were made at 0000 UT on the foregoing dates; an advancement means that the signals were adjusted to occur at an earlier time than before.

National Bureau of Standards
Boulder, Colo.

Discussion of The Two Cultures

February 11, 1962

Poles and Zeros of the February issue[1] touched upon a matter of vital importance to humanity, one with which I have been lonesomely concerned for over 25 years of privately applied contemplation and research, on which I am only beginning to discern directions necessary for final resolution. The comments below partly paraphrase from a very long and still decidedly incomplete manuscript of my study notes, and partly paraphrase from a recently completed but still unpublished article or philosophical dissertation which hopes to make its points to a more nontechnical group than that of the relatively erudite body of the IRE (of which I am a Senior Member).

Much as it may wish to avoid such issues, the responsibility for closing the gap between human cultures rightfully belongs to the body scientific. Though it shrinks the responsibility, though it steadfastly refuses to ply its intelligence and knowledge in such directions, it is the only large and competent group which has *both* enough knowledge and enough intelligence on which to build new understandings and synthesis needed for the immediate preservation of humanity from nuclear devastation and for the ultimate salvation of human aspiration.

Can this body, composed of engineers, physicists, chemists, natural philosophers, physiologists, psychologists, and anyone else who professes to intelligent manipulation of human knowledge, finally face up to its responsibility? Can it close the gaps of its own ignorance and face up to its own shortcomings in time to avert disaster, or will it continue to hold itself benignly aloof of such inconsequentialities as human welfare and human aspiration until after the bombs fall? In the latter event, of what consequence shall its vaunted truths and successes be measured?

If it is done at all, science must do this job through default of general society, of which science is a part. Society has always entrusted responsibility for its most important discoveries to science and engineering, has always held science accountable for explaining the inexplicable, the while it drunkenly revels in the "successes" achieved by technology. Thousands of years ago, out of all the ignorance, superstition, and idolatry of more primitive life, society perpetrated a social doctrine which has self-generated society into its present predicament, then foisted it upon an unsuspecting and highly naive science which it made subservient to that doctrine and to its own caprice and desire for "explanations" and "understandings" under that highly idolatrous doctrine. Perpetuated and amplified by the assiduous and often splendidly and ingeniously conceived effort of science, the doctrine has now grown into proportions of a menacing and fearsome gargantua which overshadows and blinds science and humanity to other important truths which the "humanists" continue to intuit but largely translate to ill-conceived and partly unworkable ideas.

We don't know if science as a body is yet ready to tackle such issues, or if it has the courage to shake off the shackles of mental subservience imposed on it by an idolatrous social doctrine, perpetuated by its own fatuous observance of a scientific discipline which is almost a carbon copy of that same social doctrine which to preponderant proportions is almost equally practiced on both sides of the iron curtain. But if it is ready, it must face up to issues like these—and *fast*.

Science is not really a culture, but more a cult. It is a self-disciplined slave to a special and narrowly restrictive scientific doctrine almost hopelessly enmeshed with and nearly indistinguishable from the social doctrine today practiced by most of world society. The doctrine permits mouthings about "truth" which it *predefines* will be found consequential to its own special tenets *and to no other tenet or circumstance*. It does not permit admittance of any other kind of evidence, frowns upon any and all investigation outside of these narrow limits, and classifies as unintelligent and irresponsible any mentality which seeks to investigate truth by any other criteria or to question the validity of those "scientific" tenets.

Science had its first chance to shake its shackles some 200 years ago, but failed to heed the warnings of the revered Immanuel Kant, who somehow knew that science had not the slightest comprehension of fundamentalities or truths underlying the superficialities which it continues to insist are its sole text. Extension of Kant's reasoning, still far from completion and necessary adequacy, makes it appear that even Kant may have been a little naive in the degree of naivity he ascribed to 18th century science. These preliminary findings imply an almost *incredible* naivity with which science has approached both its primary task and its social responsibility, incredible because science is largely composed of highly intelligent minds which ought to know better than to exclude the obvious from their contemplation the while they fatuously and assidously concentrate on arbitrary rules for evidence laid down long ago and seemingly never since examined or seriously questioned.

Huxley, with considerable insight, intuits an important facet of truth, but errs when he says that this is the only truth that matters, as if to say that some truths are human and some nonhuman. Insofar as the expression of truth of any kind is concerned, there is not and cannot be any nonhuman truth, though there can be and no doubt is, much of truth which is not presently known to humanity and may never become known to it if science does not immediately broaden its horizons. C. P. Snow recognizes a more practical approach as he speaks of welding the two senses (of truth) together in order to be able to think with wisdom, but he naively emulates science as he speaks of looking at education through fresh eyes, for this is but a reiteration of the favorite idolatry of science, a worship of superficial knowledge obtained by excessively narrow "scientific" methods.

It is not more knowledge which is required for a quick and effective welding or synthesis for understanding. Science already has enough knowledge, and enough intelligence, from which to build the long awaited and ardently desired synthesis. It has had enough knowledge for over a century, had it only heeded Kant and applied its intelligence in indicated directions; it did not do so, and by the merest coincidence has also failed to achieve or even suitably intuit the kind of synthesis of which it is capable. It will continue to fail as long as it refuses to admit evidence not of its own choosing or liking, as long as it remains subservient to society and its cherished superficialities.

Naively enough, modern science seems aware, in a kind of reluctant concession to inner spirit or conscience, that there just might be an outside chance that humanists may have some vague but incomprehensible point as they speak of some kind of human truth which science knows is definitely not encompassed by its own doctrine. How interesting this point! And how inconsequential and irrelevant it is indeed to scientific endeavor, which still yearns for a synthesis of knowledge. How naive can one get? Could it be that synthesis is but a word which science uses to express some vague inner yearning of the spirit of man, and that it has no definable relationship to rational thought or to mathematical synthesis?

We suppose that it might be interesting to know exactly and completely just what the nonvenerable McConnell means by these remarks. Though we have tried to make it clear in less than the hundred thousand or so words which might be required to merely report our still incomplete studies in these fields, we suppose it is not yet clear, and relinquish the rostrum while there is still time for the Pharisees to try to exact their customary toll in response to what we have conceived as a challenge to science and engineering to exercise their God given right to freedom of *thought*, unimpeded by arbitrary rules of Phariseeic-like restriction and regimentation.

Harold E. McConnell
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Houston, Tex.

February 11, 1962

Engineering and science are occupations whose effect on the public is the accomplishment of new things in the material world. These things may be useful, such as the products of industry, or alarming, such as nuclear weapons.

The practitioners of these arts are people of all sorts, having few characteristics in common except the skills of their trades. They occur in all ranges of character, temperament, and political belief. I know many engineers who are well-informed on

[1] Proc. IRE, p. 129; February, 1962.

politics, art, literature, psychology, history. Some are dull, some are clever, some are shrewd, some naive.

What does the world expect to find out from these people? It is as if the public felt somehow that the scientific and engineering fraternity were holding back some sort of important knowledge. Perhaps what we need to tell the public is that the engineer is very much a member of the public, and that, viewed in perspective, he has a lot of trouble accomplishing just a little bit.

This may be hard to get across in the face of the spectacular successes in the field of superdestruction. But it is quite true. The big engineering results rest on decades of accumulated scientific discoveries, whose outcome could never have been predicted. We have very little control over what can and what cannot be done. I suspect that (pardon the word) laymen think that *anything* can be done if only a big organized technical effort is financed and set going. We ought to explain the facts better.

So the first point is that scientists and engineers are people too, and cannot perform wonders to order—and that they themselves are the ones qualified to say what can and can't be done. But I do think that they know what is going on.

The second point is that an engineer or physical scientist cannot as such be expected to have much to offer on subjects such as urban blight, underdeveloped countries, or juvenile delinquency. He should, of course, speak up when someone else is talking apparent nonsense; but he has to speak as a nonspecialist.

The third and most important question is: how free is he to speak at all? Nearly all scientists and engineers are full-time salaried employees of organizations, and are restricted from public communication in about the same way as military officers.

Exceptions are academics, such as Linus Pauling, and heads of companies, such as Bernard Benson, who often have a great deal to say to the public. Whether it is worthwhile is a matter of opinion. It is better than nothing.

But most of us are inclined to feel that we are, as employees, risking a breach of propriety if we write or speak publicly any positive or critical thoughts on any subject whatever. In the technical field, the employed engineer is nowadays always barred from publishing anything without the consent of his employer. And in fact the clearance depends on the advantage to the organization rather than the technical importance of the information. Thus in manufacturing organizations (and many government laboratories too) there is much engineering work of high quality which never reaches the literature.

In the scientific area the employer has control too; but traditionally, there is much more freedom of publication. This tradition embraces most genuine research organizations. Note that *all* the papers in the present issue of IRE PROCEEDINGS come from research organizations or colleges. It is a scientific journal, not an engineering journal.

On nontechnical subjects, there are no accepted rules, but I believe there is a general feeling that a salaried employee is expected to remain silent on any subject that could possibly affect the interests of his employer, unless he simply agrees with his employer's views—if he knows what they are. Examples would be: unemployment, automation, patent policy, government contracting policies, unions. This is discussed, I believe, in Whyte's book "The Organization Man," and elsewhere.

If your editorial point is valid, as I think it is, we can get nowhere until we arrive at some definition of the limits on freedom of speech. No definition can be found without a lot of public discussion beforehand. In engineering societies there has never been any discussion of this question at all. How about it?

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February 12, 1962

Poles and Zeros for February, 1962 recites the problem of our bifurcated cultures and invites comments thereon. On page 222 of the same issue, there appears a letter that suggests one comment: namely, that we set our own house in order first.

It is amazing to find that old chestnut, Laplacian determinism, granted such vehement support in a competent technical magazine of 1962. The simplest refutation to the "principle" of causality is contained in two words, "quantum mechanics." Somewhat more graphic, perhaps, is this: How would a giant computer determine the instant at which a Geiger counter will emit its next click? He who delves into the appropriate theory will find that there is currently no known way of predicting that instant. Only a probability distribution can be predicted, no matter how ideal the situation and no matter how much microscopic information is available.

Of course, quantum theory may be inadequate, and physics may some day discover how to make this particular prediction, but at the moment, a "scientific" basis for determinism just does not exist. Nor does any scientific basis for free will exist. The question remains open in all but a few closed minds—most of them, alas, technical.

While we are worrying about communication between scientists and humanists, we should perhaps give some thought to communication amongst the scientists themselves. Perhaps climbing down from our nineteenth-century high horse would be a good first step toward both goals.

PAUL I. RICHARDS
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February 12, 1962

You "invite comments, thoughts, and observations" concerning what you call "the interrelations of science and the humanities." Being neither a scientist nor a humanist but a dilettante as most military men are in both the sciences and the humanities, I appreciate the invitation. Being neither, I might be able to shed some unbiased understanding upon the sadly stuffy semantic situation.

Some claim the "two cultures" do not use the same language. This amazes me. For years, I have been reading and listening to both and insist that both—in this country at least—use English. Naturally, both frown upon my poor prose as pidgin putrid and I do stumble at times over their proud professional patter but the noise to signal ratio is not too bad and in spite of a lack of good error detection techniques, I have established semireliable communications both ways.

The one shaky premise upon which I base the following explanation is this. I will assume you engineers understand engineers. This is rash and perhaps highly unscientific of me but one must assume something in order to start. Second, I will assume that if I compare the humanists with engineers and/or scientists, you will understand why you rub humanists the wrong way and perhaps by inserting a corrective feedback circuit be able to dampen the debate before the whole darn system goes into wild oscillations.

First, you do not have to worry about the "interrelations of science and the humanties" for the simple reason there is no such thing. Science is an abstraction. So is "the humanties." Interrelations between them are myths. Now, the humanists view science as something which all scientists keep on an altar next to their beds within easy praying distance, but you and I know better. We know science is merely an unique type of human behavior and that most scientists merely take great pride in behaving scientific just like the humanists take great pride in behaving like a humanist.

Actually the big difference between a humanist and a scientist is not that they speak different languages but that they are looking in two different directions. Their terms of reference are 180 degrees out of phase. The humanists—in general—look at the past. The scientists look ahead. Naturally, this is a relative thing, not true in all aspects, but in general and especially historically, this is true.

Humanism started in Italy. It was a renewed study of the Latin and Greek classics by such lads as Petrarch and Boccaccio. Later, it kicked into high gear when printing was invented. It moved up into Europe where that Dutchman Erasmus talked it up to such a degree that it finally was even taken over by such Englishmen as Sir Thomas More. He even convinced Oxford students to study Greek and they have yet to break the habit.

I realize, of course, that I will have a difficult time convincing engineers, but this looking backward does have its points even if Satchel Paige did say, "Never look behind you; some one might be gaining." Just remember that Newton said, "We stand upon the shoulders of giants." The giants of the ancient world must be able to teach us something. Just because we have not found out what, yet, doesn't matter. They lived, didn't they? They must have made mistakes we can avoid.

So you engineers do not become too hep about this humanist viewpoint and go overboard, there is one bit of their propaganda about which you should be warned. One of them wrote somewhere that Britain had brilliant diplomats for centuries because as

schoolboys they studied Euclid in the original Greek. Before you start doing this, let me tell you how overrated Euclid is even in the original Greek or in any language for that matter.

I suppose because Socrates said "Define your terms," Euclid started his geometry by trying to define a point. I said he tried, because Euclid didn't tell what a point was. He told what a point wasn't. "A point is that which has no parts" was his definition. Needless to say this negative definition did not help much. How would you like to design a radio if all you knew about it was that it was a wireless?

Because the Greeks lacked a defined point from which to start, the Greeks were never able to understand motion. In fact, their lack of mathematical language had them proving that flying arrows didn't move. They even used the wrong mathematics to prove a hare couldn't catch a turtle. We do not even need mathematics to know a hare can catch a turtle.

It took René Descartes to define a point and create upon it his imaginative analytic geometry. Upon it in fairly rapid order has come calculus, science and the wonders of our world. René really started something with his imagined point. Note, he was looking ahead when he defined it.

In fact, René Descartes was very mucha scientist because he refused to look behind. Listen to him. "Science found in books—in those at least whose reasonings are only probable and which have no demonstrations, composed as they are of the gradually accumulated opinions of many different individuals—do not approach so near to the true as the simple reasoning which a man of common sense can quite naturally carry out. . . ."

Now of course many humanists will claim that this backward look at the classics is not all there is to their viewpoint and in this they are very correct. This F. C. S. Schiller of Oxford, for instance, has used a lot of long philosophical paragraphs to prove that man is the measure of all things but I imagine he would be quite irritated if some one agreed with him by saying, "That is correct and it is the scientists doing all the real accurate measuring these days."

Realize of course, that the humanism thread runs in all directions. In Italy, humanism went for literature and art while up in Germany centuries before the Reformation, it stressed theology, education and social betterment.

Of course, the humanistic theologians never forgave the scientists away back when the scientists were impolite enough to totally ignore theology. Most scientists are good Christians but can not see any connection between the philosophy of the gentle Christ and theology mainly because the only connection is a vague verbal one.

Of course, even humanistics educators are slightly irritated at the whole scientific world lately because a scientist down at Harvard had the audacity to experiment with pigeons and come up with an optimun method of teaching humans which actually threatens to make education a science. This, according to the humanistic viewpoint, is science at its most inhuman worst, especially since the method works so well.

And, of course, engineers must realize how unfair their advantage over the humanists is in the field of social betterment. As long as society consists of people who need things, engineers can do something about social betterment by making things for those people, while all the humanists can do about social betterment is talk about it. Engineers must admit that is definitely an unfair advantage which they should pretend not to notice.

But it is the humanists of literature and art who really have the scientists over a barrel. That includes you engineers. You just do not know about the finer things in life which you are missing. For one thing you do not understand Beauty. Worse, you do not know what Beauty has done for man.

So far, you might have noticed, or at least you might have thought, that I was taking the side of the scientists in this clash of the Two Cultures. Not at all. I am not biased. And although, so far, my words may have given the scientists a little edge, my final point is that the vast ignorance of scientists concerning Beauty and its impact upon our world definitely balances the scale.

Beauty has had impact. In fact, my thesis is, man searched for Beauty and the bomb went boom!

Naturally, the humanists blame the scientists for the atomic bomb. Actually, the scientists only finished the job. It was the artistic humanists in Italy in their mad search for beauty which started it all.

Look at the Last Supper. Note its depth. Perspective was developed by artists. From the rules of perspective it was only one step to projective geometry, the first nonEuclidean geometry. Euclid did not include time in his static geometry and in figuring out the confusion between Euclid's fifth proposition and nonEuclidean geometry which defined parallel lines as meeting at infinity, Einstein realized the impact of time upon mathematics and wondered what impact it would have upon physics, which can only be understood in mathematical language. The result of his wonderment was $E=MC$ squared. It was man's search for Beauty which caused the atom bomb. Definitely, it was those darned beatnik artists which started the whole deal.

Now, perhaps all scientists and engineers will appreciate the value of Beauty and pay more attention to it.

Another good point the humanists have is their stress on the value of "good literature" to which the vulgar Jack Woodford always added "Whatever that is." Unfortunately, by past standards, one is unable to determine what "good literature" is being written these days since the word "good" is rarely placed in front of the word "literature" until that literature has been written at least fifty to a hundred years or more. However, if you desire to really learn English, check with a good computer expert. They know much more about how English works than most English professors. However, believe me, the latter may not appreciate your strictly utilitarian viewpoint.

Naturally, where the humanists really have it over scientists is their vast knowledge of human values. Scientists are just looking the wrong way, while for the humanists, all of history is there for them to study. This is why the scientists are so much more optimistic than the humanists. The scientists are not looking at the historical mess. They are looking at the future. They have no conception of human values. All they know about are human hopes and dreams. This is their speciality.

Incidently, do not confuse human values with the word value used in value engineering or value analysis. Just because you very precisely define your meaning of value and point out that there are different sorts of value such as use value, esteem value, cost value, and exchange value, does not mean the humanists must copy you. To clarify something in such a cold surgical manner just isn't human. Besides it takes all the beautiful human mystery out of it. That would be making a humanist scientific. And that is one type of behavior the humanist is not ready for yet. One has to think to be a scientist; humanists only feel.

I really appreciate, Mr. Editor, your kind invitation to bring this clarification concerning the humanistic viewpoint to your readers. I do believe that the moral of the story is that there is actually nothing to fear as long as the scientist is looking in one direction and the humanist is looking in the other; they should not bump into each other too often in spite of the fact that the humanist is walking backwards into the future. Further, you all should remember that time is on the side of the scientist, for what he is writing now, one hundred years from now will be the classics. A hundred years from now your "PROCEEDINGS" will be read far more than most humanistic literature of today.

I do hope that this middle of the row (meaning dispute) unbiased viewpoint will assist in filling that which Snow points out as a desperate need for intimate understanding and mutual cooperation. I do not believe your tolerant motto should be "You go looking your way; we'll go looking our way. Confusion, stay away from our door!"

MAJOR BERT DECKER, USAF
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February 16, 1962

Does anyone really, seriously, think that we can *do without* a dialogue between the scientists and the the humanists? If they do, there is cause for concern. Do ends have to be related to means? Our "culture" is going somewhere, and the means it uses will be partly technological. Will it arrive at the desired objective? In our democratic system, this objective is supposed to be determined by the public philosophy. For this objective to be realistic and attainable, there has to be a connection between the means and the end, between science and the humanities, between technology and the public philosophy, between our technological society and the objectives toward which it aspires. (I use "public philosophy" in the sense developed by Max Ways in his book *Beyond Survival.*)

This is a theme, a thesis, a conclusion that I have drawn out of a number of studies over the past several years. Let me offer some selected references to illustrate

what I mean; to show something of the connections that must exist between the humanities and science; to offer you a basis for drawing your own conclusion.

" 'Give us this day our daily bread.' In mid-twentieth-century America, bread is a drug on the market. Our problem is not to get bread, but to get rid of it. The breaking of this age-old economic equation is, in the sweep of history, just as new as the atom—and much less appreciated." (Henry R. Luce, "A Speculation About A.D. 1980," *Fortune*, vol. LII, No. 6, p. 105; December, 1955.)

Mr. Luce may have exaggerated in order to get our attention. On the other hand, he points to a problem that is an outgrowth of technology. What do we do when there is enough? The problem is the development of a proper system for distribution of surplus. And there are other technology-connected problems: (They appear to *me* to be connected with technology, in many ways):

". . . societies in the less developed areas of the world are caught up in the whirlwinds of concurrent revolutions—social, economic, ideological, and technological; . . . old institutions are crumbling right and left without new ones to take their places; . . . populations in many places are growing faster than resources; . . . communism—for all its sins—waits alertly to capitalize on turmoil not of its own making; and . . . there is a desperate lack of capital, of know-how, of management, and of the institutions needed to guide pre-industrial and pre-democratic societies through the agonies of violent change—quickly enough to meet aspirations and smoothly enough to avoid political retrogression. And people who worry about such things tend to suspect that this may be just about the toughest, most complicated, subtle, and sophisticated problem that anyone has ever faced." (Thomas W. Wilson, Jr., in "The Easy Chair," *Harper's*, June, 1959.)

An Indian authority, P. C. Mahalanobis, says that the industrialization of underdeveloped countries is inescapable, and that this transformation will "reduce the sphere of conflicting interests; and hence decrease the tensions between the East and West." ("Industrialization of Underdeveloped Countries," *Bulletin of the Atomic Scientists*. vol. XV, No. 1, pp. 14, 17; January, 1959.)

Will it, really? I doubt it. Is reduction of tensions the real goal? Will industrialization (the application of technology) lead to it?

Consider also:

"It is hardly farfetched to suggest that in another fifty years there will be just a few great technological systems—if we are lucky, only one—in which the borrowing process will have gone much further than today and in which the emphasis upon science and technology will have far outstripped that which is already evident. Technology *succeeds* and the success has moved at a whirlwind pace. All technological societies will have to become more and more alike." (Gardner Murphy, *Human Potentialities*. Basic Books, p. 56; 1958.)

What will they be like when they are alike? Like the objective established by the public philosophy?

All this presumes that the public philosophy is active enough to be capable of formulating an objective or objectives. There is some evidence that it is not active:

"Our greatest new industry is evidently the production of techniques to eliminate conflict, from positive thoughts through public relations to psychoanalysis, applied everywhere from the couch to the pulpit. Our national aspiration has become peace of mind, peace of soul. The symptomatic drug of our age is the tranquilizer." (Arthur M. Schlesinger, Jr., "The Decline of Greatness," *Saturday Evening Post*, vol. 231, No. 18, p. 70; November 1, 1958.)

Maybe science is busy generating tranquilizers that incapacitate the public philosophy so that the dialogue between science and the humanities has become difficult or impossible. This does not vitiate the basic premise, that science leads to technology which culturally is a means, not an end.

Scientists are part of the "body politic," and are entitled to take part in the formulation of the public philosophy. Inactivity of the public philosophy has led some scientists to talk like humanists. This is good, provided they are able to think like humanists; provided their humanistic talk is truly humanistic and not unconsciously influenced by the scientist side of their nature; provided they recognize that, humanistically speaking, science is a means not an end.

Let me illuminate this theme from just one more vantage point before you go away. In our democratic system the public philosophy is determined by the body politic comprised of citizens. Science and technology will influence the future probably even more than they are influencing the present. For the citizens to formulate a realistic public philosophy, they *must* know something of science and technology. The "Compleat Citizen" dare not be ignorant of the social or cultural or humanistic implications of science and technology. If the average citizen is inadequately informed, the scientist's task is to inform him, not to pre-empt his function. The task may be a difficult one, but this difficulty doesn't make it unnecessary.

I could go on. But if you are still with me, maybe you see now what I mean, whether you agree with me or not.

COLONEL JOHN G. JOHNSON, U. S. ARMY
U. S. Army Signal Intelligence Agency
Arlington Hall Station
Arlington, Va.

P.S.—I just now remembered a *Fortune* editorial of some months ago: "Why the U. S. is not on the Moon." Some of their arguments pertain. J. G. J.

February 16, 1962

There is a pressing need for better communication between individuals trained in science and individuals trained in humanities. The need can be satisfied only by efforts of both groups, as you have stated. In my opinion, this effort can be enhanced by study of general semantics.

General semantics is concerned with symbols, abstractions, and meanings. As an example of the utility of general semantics, you have stated in your editorial "It would be interesting to really understand, completely, what the venerable Mr. Huxley means by that." If your statement is interpreted literally, you want to understand the statement absolutely which is impossible in experimental science, but is possible in abstract theory where postulates and axioms related to undefined terms make absolute classifications possible. However, if your statement is interpreted for its communicative content in the way in which (presumably) you intended it, you want to understand the statement as well as is possible.

The reason for belaboring this example is the opinion I hold that many engineers interpret statements literally when communication is intended rather than accuracy. Since most language is used informally, this is a semantic sin.

The study of general semantics will clarify such issues and allow sharper distinctions to be drawn between what we understand based on experimental evidence and what we understand based on manipulation of abstractions. This can provide a meeting ground for scientists and "humanists."

ARTHUR WEINER
Electronic Defense Labs.
Sylvania Electronic Systems
Mountain View, Calif.

March 16, 1962

The *Poles and Zeros* Column in the February issue of the PROCEEDINGS draws together some very interesting quotations from distinguished people on the interplay between the natural and social sciences with implicit overtones of morality. Each quotation is worthy of an individual essay so I shall attempt here to convey a few sparks of thought on only one quotation, that of Aldous Huxley. I quote here from the column, words taken from Huxley's "Point Counterpoint." ". . . all these famous theories about the cosmos and their practical applications—they've got nothing whatever to do with the only truth that matters. And the non human truth isn't merely irrelevant; it's dangerous. It distracts people's attention from the important truth. It makes them falsify their experience in order that lived reality may fit in with abstract theory."

I may be grossly misinterpreting what Huxley really meant with those words, nevertheless I shall venture a nonexpert opinion. And should this opinion be shown to be a misinterpretation I shall at least have achieved an expression of my own ideas concerning the interplay of natural science, social science and morality. I include morality in the discussion for I feel that social sciences cannot divorce themselves from morality even if, in the materialistic mind, morality is believed to be simply a social force directing individual action toward harmony for the majority.

In his grouping of "famous theories" Huxley undoubtedly had in mind not only

the abstract theories of various philosophers expounding the existence of a higher order of the universe than man can visualize, but also all religions based on the existence of a divine nature.

Huxley's human truth or "the only truth that matters" embraces the natural sciences and the social sciences. But to Huxley, social science is limited to the study of natural interplay between people and matter. To him social forces are earthly generated actions resulting from the highly developed animal nature of man. He excludes from his belief any idea of an absolute truth which cannot be changed by man and which forms the basis of morality.

After accepting Huxley's view that only his human truth is of consequence, it naturally follows that attention given to nonhuman truth is dangerous in that it not only detracts from concentration on human truth but also falsifies experience equated to abstract theory.

It is rather naive of Huxley to consider nonhuman truth irrelevant, however. For even if his basic premise of the nonexistence of a divine nature were true, the mere fact that great portions of society have embraced beliefs in a divine nature gives the so-called abstract theories a very real place in society and therefore renders them anything but irrelevant.

My personal opinion is that the nonhuman truth defined by Huxley is of far greater importance than his human truth. For I accept the existence of a divine nature, making it clear to me that man's relationship with the divine is much more important than his relation with the natural sciences. I would not be so naive, however, to neglect the human truth or even relegate it to the domain of the unimportant. Man is by his nature a dual-personality, concerned with both the natural and supernatural sciences. Thus how can one nature (dealing with human truth) be irrelevant to the other nature (dealing with nonhuman truth)? At the very least man must concern himself with the human truth in order to direct his activities toward the pursuit of nonhuman truths.

In conclusion, we live in a complicated world which is a blend of the natural and supernatural. Both are very real even though some seek men to avoid the one in pursuit of the other. I must contradict Huxley in that I feel that the nonhuman truth must be emphasized more. It is very apparent that today the concentration on human truth far exceeds the pursuit of its complementary nonhuman truth. I shall not be so bold as to presume to know what the proper balancing point is, but I feel safe in saying we are so far overweighted with concentration in human truth that we should do well to exert our efforts in the other direction. Our own natural concern for human truth carries its own incentive for avoiding unbalance in the direction of nonhuman truth.

Fred Liguori
3 Forest Circle
Winchester, Mass.

Contributors

Wilbur H. Highleyman (S'55–M'58), for a photograph and biography, please see page 243 of the February, 1962, issue of these Proceedings.

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Gerald Holton was born in Berlin, Germany, on May 23, 1922. He received the Nat. Certif. Engineering, in 1940, from the School of Technology, Oxford, England, the B.A. and M.A. degrees from Wesleyan University, Middletown, Conn., in 1941 and 1942, respectively, and the M.A. and the Ph.D. (in physics) degrees from Harvard University, Cambridge, Mass., in 1946 and 1948, respectively.

In 1960–1961 he was a National Science Foundation Faculty Fellow at the University of Paris, France. At present he is Professor of Physics and Chairman of the Committee on Degrees for Chemistry and Physics at Harvard University. His particular interests are the physics of matter at high pressure and ultrasonics. In the Spring of 1962 he will be an Exchange Professor at Leningrad University, USSR.

Prof. Holton is a member of the American Physical Society, the Association of Physics Teachers, Acoustical Society, AAAS, History of Science Society, Philosophy of Science Society, and a Fellow of the American Academy of Arts and Sciences and the Société Européene de Culture. In 1961 he received the Outstanding Achievement Citation in Honor of Scholarship from Wesleyan University.

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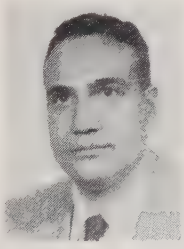

Eliahu I. Jury (M'54–SM'57) was born in Bagdad, Iraq, on May 23, 1923. He received his undergraduate training at the Haifa Institute of Technology, Israel, and was awarded the E.E. degree in 1947. He received the M.S. degree fron Harvard University, Cambridge, Mass., in 1949, and the Sc.D. degree from Columbia University, New York, N. Y., in 1952, both in electrical engineering.

He worked at the Electronics Research Laboratory in the Electrical Engineering Department of Columbia University, from June to December, 1953. He then joined the faculty of the University of California at Berkeley, in 1953, as an Instructor. In 1958 he was appointed an Associate Professor of Electrical Engineering at the same institution. He has been very active in the field of sampled-data control system and has served as a Consultant to the Bell Telephone Laboratories and Convair in this area. In 1958, while he was in Europe, he gave a series of lectures on sampled-data systems at the University of Paris and the Eidgenossische Technische Hochschule in Zurich, Switzerland.

Dr. Jury is a member of the AIEE, Sigma Xi, Eta Kappa Nu, Tau Beta Pi, and the Harvard Engineering Society.

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John L. Kelly, Jr. (M'60) was born in Corsicana, Tex., on December 26, 1923. He received the B.A. degree, in 1950, the M.A. degree, in 1952, and the Ph.D. degree in physics, in 1953, all from the University of Texas, Austin.

He has been with the Bell Telephone Laboratories, Murray Hill, N. J., since 1953, working in information theory, visual and acoustic signal coding problems, and computer programming. Currently he is Head of the Information Coding Research Department.

Dr. Kelly is now serving on the Administrative Committee of the IRE-PGIT.

Seymour Okwit (A'55–SM'61) was born in New York, N. Y., on August 31, 1929. He received the B.S. degree in physics from Brooklyn College, N. Y., in 1952, and the M.S. degree in applied mathematics and physics from Adelphi College, Garden City, N. Y., in 1958. He is presently working toward the doctoral degree in mathematical physics at Adelphi College.

From 1952 to 1954 he was in the armed forces. He was assigned to the detection division of the Chemical and Radiological Laboratories of the Army Chemical Center, Edgewood, Md., where he did extensive development work on instrumentation for the detection and analysis of the poisonous "G" nerve gases. From 1954 to 1955 he was associated with the Radar Department of Arma Corporation, Garden City, N. Y., where he was concerned with boresight studies on monopulse antennas.

In 1955 he joined Airborne Instruments Laboratory, Melville, N. Y., as an Engineer in the Department of Applied Electronics. Since 1958 he has been responsible for solid-state devices such as low-loss circulators, low-level ferrite limiters, parametric amplifiers, cavity and traveling-wave masers and superconducting devices. He is now a Section Head in the same department, currently directing programs in these areas.

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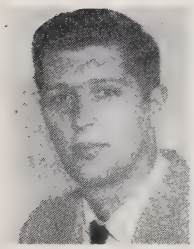

Stanley J. Schmidt (S'56–M'58) was born in New York, N. Y., on February 3, 1937. He received the B.S. degree in electrical engineering from Rutgers University, New Brunswick, N. J., in 1957.

He has been employed for the last three years in the Communications Research Division of the Institute for Exploratory Research, U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J. During this period his work has taken him to Northern Greenland on three summer expeditions to study radiowave propagation over and through thick ice, and once to Antarctica.

Mr. Schmidt is a member of the Arctic Institute of North America and the American Polar Society.

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Oliver G. Selfridge, for a photograph and biography, please see page 1441 of the May, 1962, issue of these PROCEEDINGS.

Joseph G. Smith was born in Brooklyn, N. Y., on July 16, 1932. In 1955 he received the B.E.E. degree from the College of the City of New York, N. Y. and is currently working toward the M.S.E.E. degree at the Polytechnic Institute of Brooklyn, N. Y.

He was with the Servo Components Department of Sperry Gyroscope Company, Great Neck, N. Y., in 1955 before joining the service. In 1957 he joined the Bendix Aviation Corporation, Red Bank Division, Eatontown, N. J., where he worked in their gaseous discharge device group. He joined Airborne Instruments Laboratory, Melville, N. Y., in 1958. He has been associated with the Applied Electronics Department, concerned with the design and development of cavity and traveling-wave masers, ferrite and superconducting devices.

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S. F. Sun (M'59–SM'59) was born in Canton, China, on December 11, 1922. He received the B.Sc. degree in electrical engineering from the University of Chekiang, Hangchow, China, in 1946; the M.Sc. degree in engineering from the University of London, England, in 1953, and the Dr.Sc. degree in technology from the Swiss Federal Institute of Technology, Zurich, Switzerland, in 1955.

During 1946 to 1948 he was Assistant Professor at the University of Chekiang, and thereafter, Design Engineer on electrical machinery in Shanghai, China. He joined the British Thomson-Houston Company, Rugby, England, in 1949 as Training Engineer on electrical machines and equipment for two years. In 1951 he began his post-graduate study at the University of London King's College, doing research on parasitic losses of synchronous machines.

From 1954 to 1958 he was a Research Scientist in the Department of Advanced Electrical Engineering, Swiss Federal Institute of Technology. During this time he was engaged primarily in the application of solid-state devices to the field of measurement and regulation. In 1958 he became associated with industry, to develop electronic watthourmeters, digital instruments, analog-computing devices, and transistor circuitry. Since 1961 he has been engaged in research on the microwave application of semiconductors at the Institute of High-Frequency Technology, Technical University of Stuttgart, Germany, as a Research Fellow sponsored by the German Research Foundation, Deutsche Forschungsgemeinschaft.

Amory H. Waite (SM'59) was born in Boston, Mass., on February 14, 1902. He received the Diploma in electrical engineering from the Lowell Institute School, Massachusetts Institute of Technology, Cambridge, in 1926.

He served four years in the United States Navy as a Radio Electrician. In 1929 he joined the Shortwave and Television Corporation, Boston, where he helped develop and build the first television station in New England, and the first device for televising motion-picture film. He spent 19 months in the Antarctic with Byrd's Second Antarctic Expedition, during which he was one of three men who relieved Byrd from his isolated advanced base in the midwinter night of 1934. In 1941 he joined the Signal Corps as an Electronic Engineer and became coordinator for the Signal Corps Arctic and Antarctic Research Team, USASRDL. He has participated in nine Antarctic Expeditions, including five in the International Geophysical Year Program, and in eight Arctic expeditions. He has received a special Congressional Medal, a Bronze Star for combat service in the introduction of multichannel radio relay equipment, and the Award for Exceptional Civilian Service for service in Japan in 1945 and in Antarctica in 1946.

Mr. Waite is a member of the Arctic Institute of North America, the American Polar Society, and the New Zealand Antarctic Society.

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Paul K. Weimer (A'43–SM'51–F'55) was born in Wabash, Indiana, on November 5, 1914. He received the B.A. degree from Manchester College, North Manchester, Ind., in 1936, the M.A. degree in physics from the University of Kansas, Lawrence, in 1938, and the Ph.D. degree in physics from The Ohio State University, Columbus, in 1942.

From 1937 to 1939 he taught physics and mathematics at Tabor College, Hillsboro, Kan. Since 1942 he has been engaged in research at RCA Laboratories Division, Princeton, N. J., where he has participated in the development of various types of television pickup and display tubes. He is a coauthor of the basic papers on the image orthicon and the Vidicon. During 1959–1960 he was the recipient of an RCA fellowship for study abroad and spent the year as a Research Associate at the Laboratoire de Physique, École Normale Superieure, Paris, working in the field of semiconductors.

Dr. Weimer is a member of the American Physical Society. He received a Television Broadcasters' Award in 1946 and the IRE Vladimir K. Zworykin Television Prize in 1959.

Report of the Secretary—1961

To the Board of Directors
The Institute of Radio Engineers, Inc.

Gentlemen:

The Secretary's Report for the year 1961 is transmitted herewith.

The IRE continues to increase its membership, the percentage for the year being 9 (see Fig. 1 and Tables I and II). Two new Sections were established in other countries and the Section membership outside of North America increased 45 per cent. A slight decrease, however, is to be noted in the International Convention attendance, although the number of exhibits and the number of papers presented were greater than for the year before.

The statistics show that all departments functioned effectively. An effort was made to conserve members' time by reducing, where possible, duplications in meetings.

The new building on Fifth Avenue, New York City, was fully outfitted and occupied, thereby relieving a space shortage.

Respectfully submitted,

Haraden Pratt
Secretary

January 31, 1962

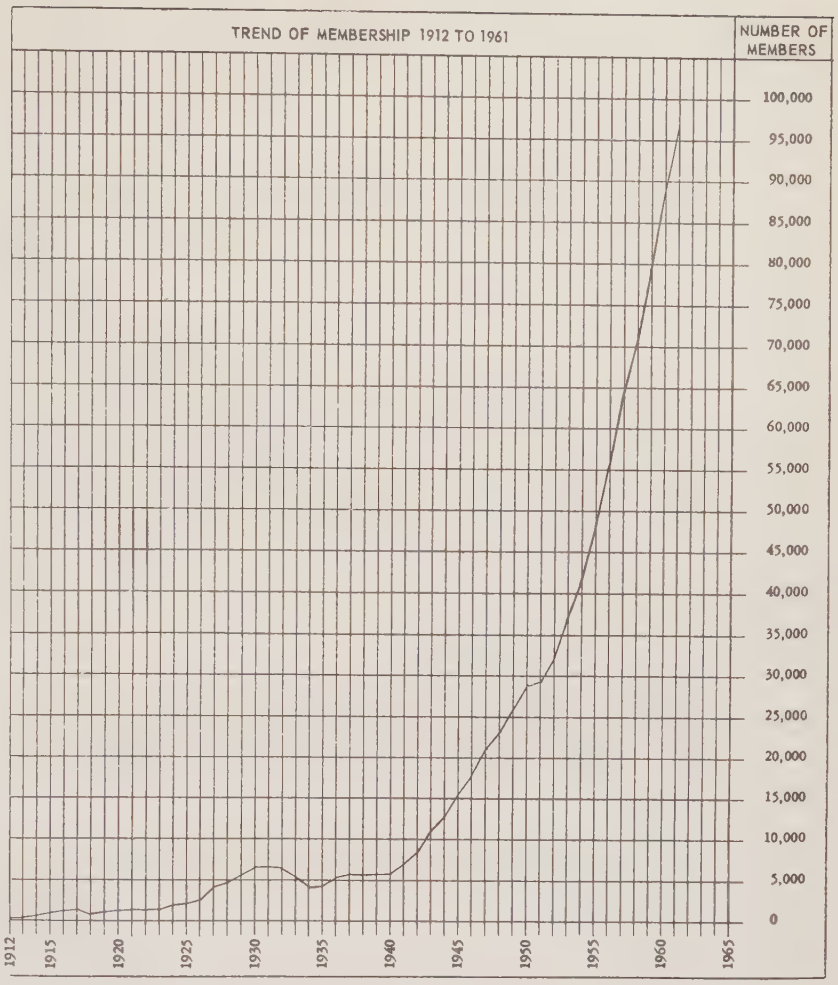

Fig. 1.

Professional Group Activities

General

During 1961 28 Professional Groups operated actively within the IRE. A 29th Group—the Professional Group on Geoscience Electronics—was organized in November 1961 and will be in full operation in 1962.

The majority of IRE members belong to one or more Professional Groups. The Professional Groups have a total membership of 87,060, which includes 7,325 IRE student members who have joined the Groups at the special student member rate of $1.00 annually. Under the Affiliate Plan 702 scientists and medical doctors, whose major interests lie in fields other than electronics have affiliated with 25 of the Professional Groups.

IRE Headquarters has rendered financial and editorial assistance to the Groups in 1961. The Office of the Professional Groups Secretary provided administrative services for Group operations, the planning of meetings, advance publicity and mailings for all Group activities which included approximately 700 mailings to Group members during the year.

TABLE I

Total Membership by Grades, 1957–1961

Grade	As of Dec. 31, 1961		As of Dec. 31, 1960		As of Dec. 31, 1959		As of Dec. 31, 1958		As of Dec. 31, 1957	
	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total
Fellow	964	1	896	1	823	1	770	1	700	1
Senior Member	10,570	11	10,001	11	9,463	12	8,536	12	7,685	12
Member	52,284	54	47,114	53	38,977	49	32,373	45	26,115	40
Associate	13,566	14	12,806	15	13,165	17	14,721	21	16,827	26
Student	19,167	20	17,662	20	16,738	21	14,961	21	13,446	21
Totals	96,551		88,479		79,166		71,361		64,773	

TABLE II

Geographical Membership Distribution, 1957–1961

	1961	1960	1959	1958	1957
Total	96,551	88,479	79,166	71,361	64,773
U. S. and Possessions	88,956	81,634	73,044	65,786	59,961
Other Countries (incl. Canada)	7,595	6,845	6,122	5,575	4,812
Per cent Other Countries	7.9	7.7	7.7	7.8	7.4

Symposia

The Professional Groups are responsible for the procurement of papers and actual management of national symposia. Each Group sponsored one or more technical meetings during this year, in addition to technical sessions at the IRE International Convention, the WESCON. The National Electronics Conference and other jointly sponsored meetings, for a total of 59 meetings of national and international import in 1961.

In an effort to minimize the number of meetings per year and to assist in reducing the general demand on man hours of industry personnel, many of the Group meetings have been successfully joined with those of other Professional Groups and other professional societies.

International Activities

In order that Professional Group activities may be expanded into international areas of interest, three of our Professional Groups have representation in the following international societies: 1) PG on Automatic Control—International Federation of Automatic Control, 2) PG on Bio-Medical Electronics—International Federation for Medical Electronics, and 3) PG on Electronic Computer—International Federation for Information Processing Societies.

The Professional Group on Bio-Medical Electronics joined with the International Federation for Medical Electronics in sponsoring the 4th International Conference on Medical Electronics held in New York City in July, 1961. Three hundred papers were presented in 36 sessions in addition to six workshop sessions and 80 exhibits. The meeting was attended by 3,000 people from all parts of the world.

Five of the Groups—The Professional Groups on: Antennas and Propagation, Circuit Theory, Information Theory, Instrumentation and Microwave Theory, and Technique co-sponsored the URSI Spring and Fall Meetings.

Publications

During the year all 28 Groups published Transactions many of which included the proceedings of their national meetings in one or more issues. Full details on Group Transactions are included in the report of the Editorial Department.

Chapters

Chapter growth is continuing at a healthy rate. At present there are a total of 303 active Professional Group Chapters operating in 57 IRE Sections (listing in Table 4 of Section B). Most of the Chapters meet regularly and sponsor meetings covering the fields of interest of their associated Groups in the various Sections of IRE. Chapter meetings held in 1960 and 1961, by Group and by Section, are recorded in Section F, Table 3.

Editorial Department

Proceedings of the IRE

Plans for an extensive series of review and tutorial papers were initiated during the year, with the objective of publishing one to two such papers in every issue, starting early in 1962. Steps were also taken to reduce by three weeks the minimum time required for publishing letters to the editor. The Correspondence section, which has grown substantially in size and value during recent years, expanded from 280 letters in 1960 to 449 in 1961.

The year highlighted by the appearance of two special issues of the Proceedings: "Electronic Computers" in January and "Plasma" in December. The total number of papers published, 131, was less than the previous year's total of 174 due to less bulky special issues. However, the total number of Proceedings editorial pages remained substantially the same, as shown in Table III and in Fig. 2.

The number of papers reviewed for the Proceedings increased 13% to 292 papers totalling 2475 pages. Of these, 26% were accepted, 41% were referred to the Transactions for publication consideration, and 33% were rejected. These ratios were approximately the same as in 1960.

Ten IRE Standards were published in the Proceedings, an increase of 3 over 1960. In addition, an index to the Abstracts and References section was provided as Part 2 of the May issue.

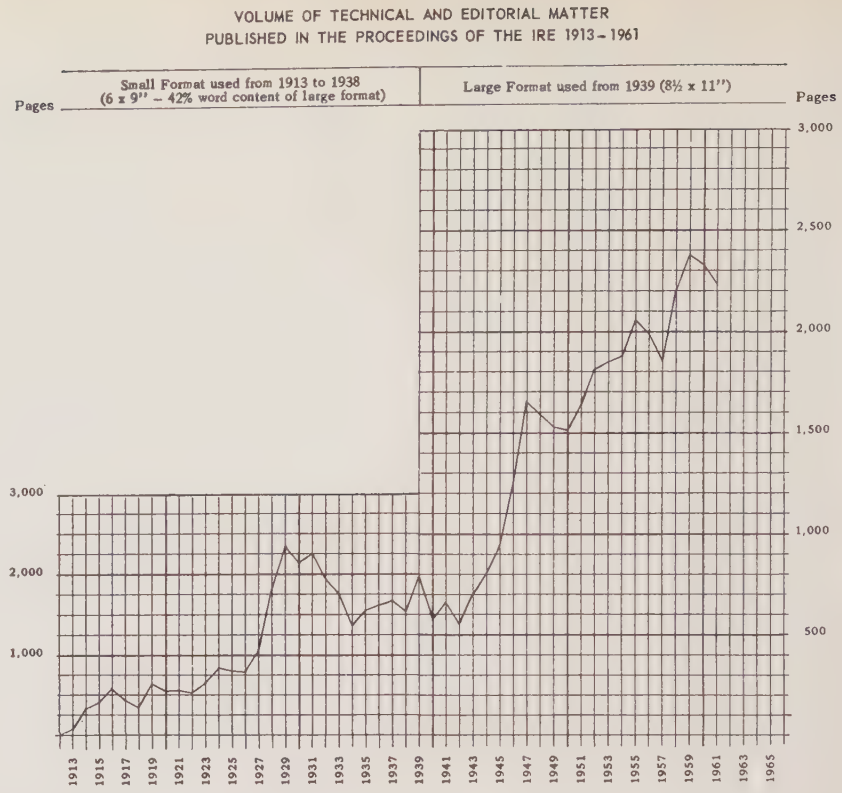

Fig. 2.

TABLE III
Volume of Proceedings Pages

	1961	1960	1959	1958
Editorial	2,234	2,325	2,370	2,199
Advertising	2,070	2,485	2,760	2,169
	4,304	4,810	5,130	4,368

Transactions

The tenth anniversary of the Transactions found the Professional Groups maintaining a high volume of publishing activity while increasing the selectivity and regularity of their publications. The number of papers and letters (1,215) and the total pages (8,336) published in Transactions in 1961 represented half of the total IRE output of 2,082 articles and 16,922 pages. Total pages are given in Fig. 3. It is noteworthy that 14 Transactions appear quarterly and that 4 Transactions are now published 6 times a year.

IRE Convention Record

The 1961 IRE International Convention Record, published in 10 parts, contained 241 papers and 16 abstracts totaling 2,164 pages. The IRE WESCON Convention Record, which has appeared annually since 1957, was discontinued in 1961 by the WESCON Board of Directors.

IRE Student Quarterly

W. Reed Crone joined the IRE Headquarters staff as Student Affairs Secretary in September. His duties include assisting in the publication of the IRE Student Quarterly. Four issues of the Student Quarterly, totaling 224 pages, were sent free to IRE Student members during the year. In addition, approximately 24,000 free copies of the September issue were distributed to all non-IRE junior and senior electrical engineering students.

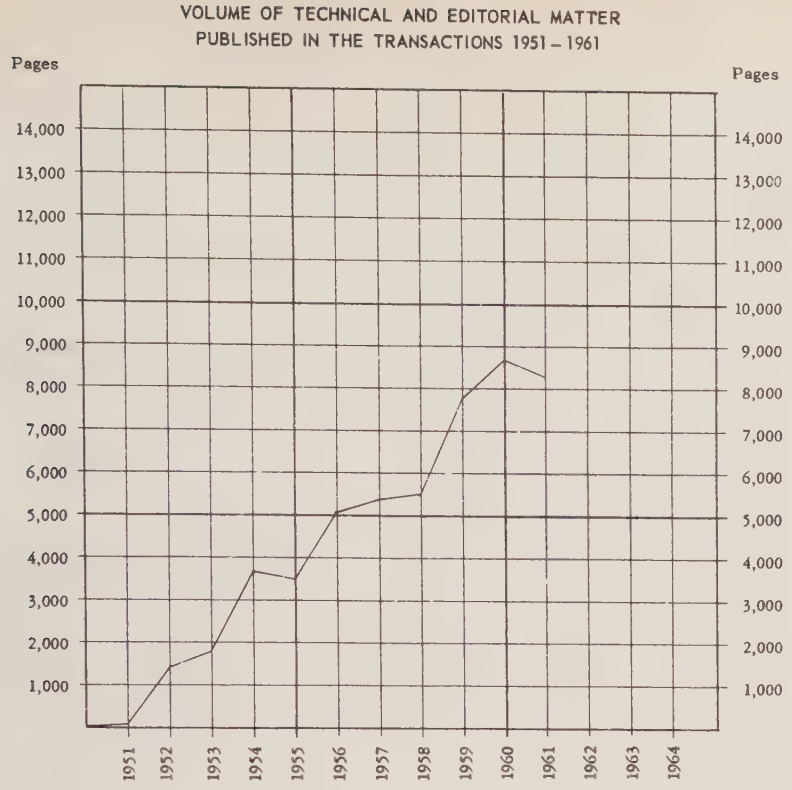

Fig. 3.

IRE Directory

The 1962 IRE Directory, which was published in November, 1961, contained 1,612 pages including covers, of which 713 were membership listings and information and 899 were advertisements and listings of manufacturers and products.

IRE Dictionary

A 242-page *IRE Dictionary of Electronics Terms and Symbols*, containing all definitions of terms and graphical and letter symbols which have appeared in IRE Standards over the past 18 years, was completed and issued in January, 1961

Technical Activities

Technical Committees

During 1961, 26 Technical Committees and their 130 Subcommittees and Task Groups held 223 meetings, of which 204 were held at the IRE Headquarters and 19 throughout the nation.

The ten Standards were approved by the IRE Standards Committee, and were published in the Proceedings in 1961. Reprints are now available to the public.

IRE is directly represented on 36 Sectional Committees of the American Standards Association, of which IRE sponsors three: The ASA Sectional Committee on Radio and Electronic Equipment, C16; the ASA Sectional Committee on Sound Recording, S4; and the ASA Sectional Committee on Nuclear Instrumentation, N3. Two IRE Standards received approval by the American Standards Association in 1961, and are now available overseas through its international agency and 8 were reaffirmed as American Standards.

IRE Technical Committees participated in international standardization in 1961 by reviewing and preparing comments on documents for the United States National Committee of the International Electrotechnical Commission. In addition, IRE personnel were delegated to represent the United States at four international meetings held this year.

IRE-AIEE Joint Standards Committee

On October 5, 1960 the IRE Board of Directors approved the Resolution of the Joint IRE-AIEE Task Group regarding a joint IRE-AIEE Standards Committee. Since that time the membership has been established and two meetings have been held. The committee has almost completed drawing up its by-laws and expects to distribute copies to its members very shortly. In addition, this committee has very recently faced its first test as moderator in a situation where attempts at coordination of the work of an IRE and AIEE committee involved in the preparation of essentially the same type of Standard have failed up to the present time. It is the Joint Committee's intention to block the passage of these Standards by both Institutes and resolve the differences between the two groups, if this becomes necessary. Several Standards prepared by joint subcommittees within the IRE and AIEE will shortly come before the Committee for approval as joint Standards. In conclusion, this committee is making slow but very definite progress in coordinating the Standards of the two Institutes.

IRE EIA Joint International Standards Advisory Committee

This committee's formation was approved by the IRE Board of Directors in January, 1961. There has been one official meeting, at which forthcoming meetings of IEC Committee 12 and its Subcommittees 12A, 12B, and 12C were discussed and agreement reached that IRE and EIA would each appoint a delegate to represent the United States at the respective meetings. The results of these efforts are reported below.

The International Electrotechnical Commission (IEC)

The annual meeting of the International Electrotechnical Commission was held in Interlaken, Switzerland from June 18 to June 30, 1961. Of particular significance to the IRE was the meeting of IEC SC 12C—Radio Transmitting Equipment held June 19 through June 22, 1961. Mr. Eric M. Leyton was selected by IRE to act as one of the U. S. representatives to this meeting which was the first active participation of the U. S. delegation in SC 12C. There were occasions when some of the U. S. comments were not accepted or had to be withdrawn for technical or tactical reasons. However, all in all, the U. S. delegation concluded the meetings with a genuine sense of satisfaction in view of the definite contribution it had made. Another aspect of the meeting was the perfect professional relationship which developed between the U. S. delegation and the representatives of other countries, and which also contributed to the creation of a most favorable environment for making decisions. As reported by the Secretary of the U. S. National Committee of the IEC, "It is hard to overestimate the importance of the participation of the U. S. in committee work such as 12C and others, which directly affect the interests of our electronics industry. Therefore, it is our hope that U. S. active participation in the future work of these and other similar committees will be secured."

Not included in the General Meeting but also of very great importance to the IRE were the meetings of TC 12 and SC 12A Radio Communications, held in Paris, France August 31 to September 7, 1961. Mr. Gordon S. Ley participated as one of the U. S. delegates to these meetings and the following was reported:

Three documents were thoroughly discussed and general agreement was reached so that by the end of the meetings it was decided that the Secretariat had sufficient information so that it could prepare final drafts. In the case of three other documents, final editing was accomplished and turned over to the Central Office for publication. The program for future work includes: 1) Correlation of radiation results for the several systems, 2) Acoustic Measurement, 3) Radio Stereophony, and 4) Color Television.

Finally, the meeting of SC 12B on Safety was held in Hamar, Norway from August 20 to August 27, 1961 and as the IRE appointee to the U. S. delegation, Mr. Gordon S. Ley reported that several documents were discussed and recommendations made to the Secretariat. The work laid out for the Secre-

tariat and Editing Committee is so extensive that it is not considered feasible to have a meeting next year so it was proposed to have the next meeting as part of the General Meeting in Venice in May 1963.

The program for future work includes: 1) Drip-proof and splash-proof apparatus requirements, 2) Protection against fire in Ht supplies, 3) Permissible temperatures on materials, 4) Safety capacitor requirements, 5) Testing against implosion danger, and 6) Stability testing for safety.

In accordance with customary procedure, lists of all documents and material received in the Office of the IRE Technical Secretary from the IEC were distributed to the Chairmen of all Professional Groups, Technical Committees and the members of the Joint Technical Advisory Committee.

Joint Committee for Inter-Society Coordination (JCIC)

The JCIC has been relatively inactive and held only one meeting during 1961. In 1960 the committee had requested that ASA call a conference of its Member-Bodies to discuss the desirability of forming a policy by ASA for the minimizing of duplication of effort in developing standards on a subject of common interest to more than one group. This request has been taken under consideration by a special task group which has, in turn, referred it to the Board of Directors. Up to the present time no formal action has been taken by this group.

Appointed IRE Delegates to Outside Organizations

IRE appointed delegates to eleven organizations for the one-year period—May 1, 1961 to April 30, 1962 (as listed on page 50A of the October, 1961 PROCEEDINGS).

During 1961, the Executive Committee of the U. S. National CCIR (International Radio Consultative Committee) held five meetings during which the representatives of the fourteen Study Groups summarized and reported on their activities. The Executive Committee formed an *ad hoc* committee for the purposes of making arrangements for the meetings of the International CCIR Study Groups IV and VIII to be held in Washington, D. C., March 12–23, 1962, prior to the 1962 IRE International Convention. Lists of all material received at IRE during 1961 were distributed quarterly to the Chairmen of the IRE Technical Committees and Professional Groups, as well as to the members of the Joint Technical Advisory Committee.

The Joint Annual Spring Meeting of the International Scientific Radio Union (URSI) and IRE was held in Washington, D. C., May 1–4, 1961. The Fall Meeting was held, at the University of Texas, Austin, Tex., October 23–25, 1961. These meetings were co-sponsored by the IRE Professional Groups on Antennas and Propagation; Circuit Theory; Information Theory; Instrumentation; and Microwave Theory and Techniques.

The Plenary Session of the International Special Committee on Radio Interference (CISPR) was held at the University of Pennsylvania, Philadelphia, Pa., October 1–6, 1961. The PGRFI supported this meeting. Lists of documents received at IRE Headquarters during 1961 were distributed quarterly to the Chairmen of IRE Technical Committees and Professional Groups, as well as to the members of the Joint Technical Advisory Committee.

The Council for the American Association for the Advancement of Science (AAAS) held its 128th Annual Meeting December 26–31, 1961, in Denver, Colo.

The National Bureau of Standards (NBS) IRE Technical Advisory Committee is divided into six groups. Individual group meetings have been held periodically during 1961.

The National Electronics Conference (NEC) held its Annual Meeting October 9 to 11, 1961, in Chicago. This meeting was sponsored by the AIEE, Illinois Institute of Technology, IRE, Northwestern University, the University of Illinois, *et al.*

The Joint Technical Advisory Committee (JTAC) of IRE and EIA

The Joint Technical Advisory Committee held a total of nine meetings for the period July 1, 1960, through June 30, 1961. The Thirteenth Anniversary Dinner was held in May 1961 at The Waldorf-Astoria, New York City.

The JTAC *ad hoc* Subcommittee 60.2 was established in July 1960 to study problems posed by the FCC's inquiry into the allocation of frequency bands for space communication of an industry-wide nature. The

TABLE IV

1961 SUMMARY OF INCOME AND EXPENSE

Income		
Advertising	$1,600,766	
Member Dues and Convention	1,863,812	
Subscriptions	238,407	
Sales Items, Binders, Emblems, etc.	176,147	
Investments	55,100	
Miscellaneous	2,037	
TOTAL INCOME		$3,936,269
Expense		
PROCEEDINGS Editorial Pages	681,353	
Advertising Pages	834,897	
Directory	363,161	
Section Rebates	97,563	
Student Program	142,573	
Professional Groups	330,212	
Sales Items	88,561	
General Operations	736,796	
Convention	579,359	
Publications	17,500	
TOTAL EXPENSE	$3,871,975	
Reserve for Future Operations—Gross		$ 64,294
Depreciation		34,041
Reserve for Future Operations—Net		$ 30,253

TABLE V

BALANCE SHEET, DECEMBER 31, 1961

Assets		
Cash and Accounts Receivable	$1,022,872	
Inventory	37,295	
TOTAL CURRENT ASSETS		$1,060,167
Investments at Cost	1,853,498	
Buildings and Land at Cost	1,601,473	
Furniture and Fixtures at Cost	377,273	
Other Assets	100,543	
TOTAL		3,932,787
TOTAL ASSETS		4,992,954
Liabilities and Surplus		
Accounts Payable	226,050	
TOTAL CURRENT LIABILITIES		$ 226,050
Deferred Income	1,499,207	
Professional Groups Funds and Deposit	252,292	
		1,751,499
TOTAL LIABILITIES		$1,977,549
Reserve for Publications	165,000	
Reserve for Depreciation	135,355	
TOTAL RESERVE		300,355
Surplus Donated	595,287	
Surplus	2,119,763	
TOTAL SURPLUS		2,715,050
TOTAL LIABILITIES AND SURPLUS		$4,992,954

Subcommittee held four meetings. JTAC submitted its report "Frequency Allocations for Space Communications" to the FCC in March 1961.

JTAC representation was requested for the FCC UHF-TV Project for New York City. Representation from JTAC was also requested for the NAS Committee on Radio Frequency Allocations for Scientific Research, the U. S. counterpart of the Inter-Union Committee on Radio Frequency Allocations for Scientific Research which was formally established by the International Council of Scientific Unions (ICSU). This NAS Committee held three meetings during 1961. It submitted a report to Federal agencies entitled "Frequency Allocations for the Radio Astronomy Service—A Statement of Position."

The JTAC Annual Proceedings for 1960–1961, Volume XVIII, was published in November 1961. Section I of the Proceedings included official correspondence between the Federal Communications Commission and the Joint Technical Advisory Committee together with correspondence pertinent to the activities of the JTAC and the JTAC Report to the FCC on "Frequency Diversity Study." Section II of this Volume contained the approved Minutes of Meetings of the Joint Technical Advisory Committee held between July 1, 1960, through June 30, 1961.

Section Activities

During the year, new IRE Sections were formed in Chile and France, bringing the total number of Sections to 111, of which 12 are outside of North America.

In addition, the following Subsections were formed in the indicated Sections: Crescent Bay (Los Angeles Section), Palm Beach (Miami Section), and Victoria (Vancouver Section). There are now 28 Subsections.

A growing major activity of many Sections and the larger Subsections in recent years is the publication of a local monthly Bulletin to fulfill the need for announcing to the Section member the increasing activities of the Section, including 1) Section Meetings, 2) Professional Group Chapter Meetings, and 3) Information on the local and national level of interest to the Section member. Fifty-nine of the Sections and Subsections now issue these monthly publications.

Student Branches

Twenty-one Student Branches were established during 1961. The total number of Student Branches is now 217, of which 128 operate as joint IRE-AIEE Branches.

Following is a list of Student Branches formed during the year: Christian Brothers, Dayton University, DeVry Technical Institute of Canada, Ecole Polytechnique (Montreal), Electronic Technical Institute (San Diego), Franklin Institute of Boston, Herald Engineering College, the University of Illinois, Long Beach State College, New York City Community College, New York Institute of Technology, Pierce College, Radio Engineering Institute, The University of Rochester, the University of Rome, San Francisco State College, Sinclair College, Southwest Missouri State, Universidad Tecnica Federico Santa Maria (Chile), Voorhees Technical Institute, and Western Michigan University.

Fiscal

A condensed summary of income and expenses for 1961 is shown in Table IV, and a balance sheet in Table V. (Preceding page.)

Books

Sensory Communication, Walter A. Rosenblith, Ed.

Published (1961) by The MIT Press, Cambridge 39, Mass. and John Wiley and Sons, Inc., 440 Park Ave., New York 16, N. Y. 824 pages +18 index pages +xvi pages +references by chapter. Illus. 6×9¼. $16.00.

In July 1959, an international symposium on Sensory Communication was held at MIT. The present volume, edited by Walter Rosenblith, contains thirty-eight papers and a number of additional commentaries by participants in that symposium. Most of the work reported is of exceptionally high quality and should be of interest to the growing number of engineers working on sensory data-processing systems and artificial "neural network" models, as well as to readers in the biological sciences, for whom "Sensory Communication" is primarily intended. The book includes papers on psychophysics, physiology of the sense organs, sensory representation in the central nervous system, and the information theoretic aspects of coding in neural networks. Some of the contents are in the nature of review papers, while others present original research results.

The main strength of this volume is in its empirical contributions, rather than its theoretical speculation. As a source-book for empirical results in sensory physiology, it is comparable to Stevens' "Handbook,"[1] and supersedes it in a number of fields. The occasional papers which attempt to deal with the theory of data-processing mechanisms in the CNS, however, may frequently seem naive and uninformed to someone who has been close to recent developments in the theory of neural networks. For example, Bullock's paper, "The Problem of Recognition in an Analyzer Made of Neurons," discusses three alternative forms that a neural "decision element" might take: a single cell, a randomly connected mass of cells, or a metastable feedback loop. While Bullock shows considerable intuitive insight into the nature of these three possibilities, he leaves an impression that theoretical studies of these alternatives have gone no further than the models proposed by Sholl and Uttley in 1953, and by Beurle in 1956. Actually, a great deal is now known about the relative capabilities and properties of these three forms of neural representation.[2] The reviewer experiences a similar reaction to some of the statements in Fessard's paper, "The Role of Neuronal Networks in Sensory Communication within the Brain." For example, with respect to the association of heterosensory input patterns, Fessard states, "The only special case that has given rise to some theoretical approach is that of association between two heterogeneous signals in the experimental situations offered by conditioning (Uttley, 1958)." This is simply not correct. Hebb, Hayek, Rosenblatt, and many others have been concerned for over ten years with theoretical studies of such processes. Again, Beurle's model[3] is frequently mentioned as a particularly plausible analysis of a statistically organized learning system, but there seems to be no recognition of the fact that Beurle's *analysis* (as opposed to his speculative inferences) has demonstrated no more than the capability of a randomly coupled network to support wave propagation.

Many physiologists would maintain that a theoretical treatment of the integrative processes of the CNS is strictly premature; that the role of the biologist should still be primarily that of an observer, a collector of data. But when a physiologist *does* aspire to a theoretical integration, it seems reasonable

[1] S. S. Stevens, "Handbook of Experimental Psychology," John Wiley and Sons, Inc., New York, N. Y.; 1951.

[2] F. Rosenblatt, "Principles of Neurodynamics," Spartan Books, Washington; 1962.

[3] R. L. Beurle, "Properties of a mass of cells capable of regenerating pulses," *Phil. Trans. Roy. Soc. of London*, vol. B240, pp. 55–94; 1956.

to demand that he should show cognizance of the current state of theoretical knowledge, and of the extent to which answers to his questions may already be available.

The converse, unfortunately, is equally true. Many well-known theorists seem to take inadequate account of the known physiological properties of the nervous system, treating in its place an arbitrary logical artifact, in the construction of their models. The examples chosen by Barlow, for instance, in his discussion of "Transformations of Sensory Messages," seem so artifactual as to be of dubious relevance to an actual biological system; and his concluding speculation "that the sensory image that is thus disseminated consists of very few impulses and perhaps only a solitary one, in a very large array of nerve fibers" seems totally insupportable on physiological grounds. This might be contrasted with the excellent empirical treatments of sensory coding in such chapters as Davis' "Peripheral Coding of Auditory Information," and Rushton's "Peripheral Coding in the Nervous System."

An ideal combination of theory and experimentation is exemplified by Ratliff's chapter on "Inhibitory Interaction and the Detection and Enhancement of Contours," or Reichardt's beautiful demonstration of autocorrelation functions in the visual system of the beetle. Bouman's "History and Present Status of Quantum Theory in Vision" also deserves special mention in this respect, although it is frustrating to find essential steps of his mathematical reasoning omitted (without references) on the grounds that they are "too difficult" for presentation.

In the various papers on psychophysics (by Stevens, Ekman, Pollack, and others) one of the most notable developments is the replacement of the traditional Fechner's Law (which holds that the subjective intensity of a stimulus is proportional to the log of its physical intensity) with a power law (the subjective intensity now being proportional to a power of the physical intensity) for a wide variety of sensory variables. Other studies which deserve special mention include the contribution on "Neural Growth in the Cerebral Cortex after Lesions Produced by Mono-energetic Deuterons" by Rose, Malis, and Baker. Here, for the first time, there seems to be some convincing evidence for the continuous growth of neural processes in the cerebral cortex, under normal physiological conditions. The paper by Lettvin and his associates should be of particular interest to those readers who have followed the earlier work of this group on the visual mechanisms of the frog. Jung's paper on "Neuronal Integration in the Visual Cortex" is an interesting predecessor to the recent definitive work by Hubel and Wiesel on this subject.[4]

Rosenblith himself, in his closing remarks, has some of the pithiest comments to offer concerning the state of knowledge and future course of research in sensory mechanisms. Admitting a prejudice in favor of the study of the most general properties of neural networks, rather than the particular mechanisms which have evolved for handling the sensory problems of particular species, he writes, "The properties that make language and other systems effective tools of communication are not likely to be discovered in the nerve nets of coelenterates. . . . An adequate theory of sensory function implies an adequate theory of brain function. And an adequate theory of brain function in its turn requires that the system's behavioral repertory be predictably related to the behavior of the elements which compose it." Of the various techniques by which such an understanding might be achieved, Rosenblith believes that the use of computers for the simulation of neural networks is one of the most promising tools at our disposal. It is through this means that the engineering community may be in a position to make a contribution of the greatest value to the study of sensory processes.

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[4] D. H. Hubel and T. N. Wiesel, "Receptive fields, binocular interaction, and functional architecture in the cat's visual cortex," *J. Physiol.*, vol. 160, pp. 106–154; 1962.

Stability by Liapunov's Direct Method with Applications, Joseph La Salle and Solomon Lefschetz, Eds.

Published (1961) by Academic Press Inc., 111 Fifth Ave., New York 3, N. Y. 130 pages+2 index pages+vii pages+2 bibliography pages. Illus. 6¼×9¼. $5.50.

In 1892 a Russian mathematician named A. M. Liapunov introduced a powerful method for investigating the stability of dynamic systems. This method, the direct or second method of Liapunov, has the merit that the stability of dynamic systems may be studied by using the form of the associated differential equations without requiring their explicit solution. Furthermore, this method ordinarily does not require a system to be specified in every detail before an investigation of stability may begin; therefore, some results of great generality may be obtained.

Unfortunately, the method was neglected by engineers in this country until about 1960. Since that time, largely due to the efforts of Kalman and Bertram, the method has become increasingly popular among engineers. To this reviewer's knowledge the monograph by LaSalle and Lefschetz is the first book in English, other than translations, which gives a detailed and rigorous account of the method. This excellent monograph should be of great value to the serious student and research engineer interested in nonlinear systems and circuits.

While written by mathematicians, tee book is for engineers, and makes only modest demands on mathematical knowledge. Chapter 1, in fact, is primarily a review of vectors and matrices. Continuing with a digest of the chapters, in chapter 2 stability is carefully defined, the Liapunov function is introduced and its properties examined; a number of stability theorems are stated and proved. The chapter also includes useful material on the extent of the region of asymptotic stability. Chapter 3 contains an interesting application of the direct method to a control problem; the basic formulation and solution is due to the Russian, Lur'ye, but, happily, the author's presentation is modern and elegant. Chapter 4 considers some miscellaneous subjects including finite escape time, practical stability and steady-state oscillations. In general the writing style is concise and eminently readable.

The following points represent a few prejudices of the reviewer. It would have been well to use bold face type for vectors and matrices, since there is frequent switching from vector to scalar equations. The book would be even more useful if there were references. The abridged literature list at the back of the book is well chosen but does not open the door to a large number of excellent technical papers that have appeared in recent years, including those of the authors.

ARTHUR R. BERGEN
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A Writer's Guide for Engineers and Scientists, by Robert R. Rathbone and James B. Stone

Published (1962) by Prentice-Hall, Inc., Englewood Cliffs, N. J. 344 pages+4 index pages+xi pages+references by chapter. Illus. 6×9. $7.95.

This reviewer, engineer by training and editor by experience, has long contended that every professional person trained in the United States has an obligation to write English in a clear and concise manner. In producing "A Writer's Guide for Engineers and Scientists," Professors Rathbone and Stone have given members of the technical profession little excuse for inability to demonstrate this minimal educational requirement. By selecting problems from the field of the physical sciences, these MIT authors have met the writer of technical prose on their own home ground. Their volume contains the elements of a handbook as well as of an anthology.

The "Guide" contains no dissertations on grammar, cases, or declensions and avoids other unhappy reminders of former school years. The reader is spared the mechanistic ritual of averaging various syllable and word counts to derive reading indices that have come into fashion in recent years. Instead, Professors Rathbone and Stone have provided common sense discussions of such topics as "Satisfying the Reader's Needs," "Explaining a New Concept, Method, or Device," Reporting Negative Results," and Developing an Effective Style," to enumerate but four of the ten chapter headings. The reader will find examples of writing—good and bad—dealing with reports on electronic circuits, digital computers, butyl insulation, and driving an automobile. He is quickly introduced to the most important single element of technical writing—an author's obligation to give careful consideration to the needs of the intended reader—a subject too frequently and flagrantly ignored by inexperienced or careless writers. The book contains many exhibits and problems, including one dealing with a formal report to a government agency.

The text is easy to read. It enumerates and critically examines a wide variety of

specific writing problems which practicing engineers and scientists are likely to encounter in their professional work. Numerous examples are given to show how greater clarity and conciseness of expression can result from a bit of care, coupled with intelligent effort. The authors explode the myth that "Pentagonese" or other jargon is a mark of erudition. To this reviewer, however, the greatest virtue of the volume is the pragmatic, practical, common sense approach which the authors adopt in treating topics that are important, but usually distasteful, to professional men working in the physical sciences.

Obviously a volume such as this "Guide" makes no pretense toward advancing the technical training of the engineer or scientist. But it should make a valuable ancillary contribution by helping the professional man to realize that his written words provide an infallible and indelible testimonial to his general education and culture. The "Guide" might even convince an enlightened management that poorly written reports or hurriedly assembled proposals wreak havoc to a firm's technical reputation. Thus, this volume is recommended reading for engineers and scientists whose professional advancement depends upon written communications. In addition, technical managers and their writers and editors would do well to become familiar with "A Writer's Guide for Engineers and Scientists."

BEVERLY DUDLEY
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Advances in Quantum Electronics, Jay R. Singer, Ed.

Published (1961) by Columbia University Press, 2960 Broadway, New York 27, N. Y. 630 pages+xvii pages. Illus. $6\frac{1}{4}\times9\frac{1}{4}$. $15.00.

This volume is a collection of the papers and discussions presented at the Second International Conference on Quantum Electronics held at Berkeley, Calif., March 23–25, 1961. It will be read with interest by radio engineers engaged in research on the generation, amplification and manipulation of electro-magnetic radiation, at optical, infra-red, microwave or radio frequencies. That such an engineer will have to call himself a quantum electronicist when he reads this book is no need for terror; since there is undoubtedly as much foreign material in the average issue of the PROCEEDINGS OF THE IRE for the relatively specialized radio engineer of today, as there is in the volume for the man no longer awkwardly uncomfortable in the presence of circulators, masers and lasers.

There are sixty-nine individual papers in the collection, divided into eight sections, including: optical masers, optical pumping, resonant structures and molecules, paramagnetic resonance phenomena, semiconductors, quantum aspects of information theory, microwave devices, and a section on new ideas and devices which, in fact, does not expand the area covered by the other seven topics. There are some fine review papers by Schawlow, Brossel, Dieke, Schlomann, to name a few, but for the most part the papers deal with a single limited topic. Fifty-seven of the 450 participants took part in the discussion, each asked an average of one and one half questions pertaining to the thirty-four papers. The characterization of the discussions ranges from provocative (such as Schawlow's comment, in replying to a question, that side bands due to lattice vibrations are visible on the ruby R lines); to abundant (the discussion of Senitzky's paper is twice as long as the much too-compact report of his paper); to mysterious (such as Javan's comment after Thorp's paper on adiabatic rapid passage inversion of populations in paramagnetic levels of ruby that an analogous technique is being used at BTL to obtain best results with a He-Ne optical maser); to comic relief (one author persistently informed four other authors that their results were in some fashion subsidiary to or corollaries of his results.)

The printing is well done, having only minor typographical errors. The 3-j symbols on page 146 are barely decipherable and on page 180 the magnetic field is measured in kilograms. The publisher is to be commended on doing such a fine job so rapidly since the material presented here is of too great an interest to too many people to be delayed by anything so unscientific as a printing press!

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An Introduction to Electric Circuit Analysis, by R. E. Armington and C. Volz

Published (1961) by Prentice-Hall, Inc., Englewood Cliffs, N. J. 244 pages+6 index pages+xi pages +5 appendix pages. Illus. $6\frac{1}{4}\times9\frac{1}{4}$. $9.00.

Consider an electrical engineering curriculum in which field concepts are emphasized in one course and circuit concepts in another—and here is an excellent circuits textbook for use by sophisticated, perhaps second-term, sophomores. Not by themselves, but with guidance and pacing provided by an instructor. The first impression of a leisurely approach is soon replaced by one of respect for the amount that can be said in so few words when mathematical language is adroitly used.

Part I, slightly more than half of the book, treats resistance, capacitance, and inductance parameters, including the ideas of conservation of charge and of flux linkages. Single-energy transients are also treated well, although generality could have been increased by use of constant-current sources (mentioned but not really used) as well as constant-voltage sources. This reviewer would prefer the symbol M for mutual inductance to the symbol L with two subscripts. Depending upon the particular curriculum, parts of the first half can be omitted or supplementary material added.

Nothing in Part II—which deals with the writing and solving of differential equations for first- and second-order linear systems—dare be omitted. It is here that the student must proceed section by section, doing numerous examples for himself, in order to master the important basic ideas of classical transient analysis. The treatment includes all of the usual drive functions as well as hints for handling the unusual ones.

The Superposition Theorem is proved, but the Thévenin and Norton Theorems are merely demonstrated. It would have been to the reader's advantage to have had these theorms proved, because the proof would have aided in grasping the subtleties involved. While not of such great importance, reciprocity might well have been proved for a general case rather than for one numerical example. The succinct appendix on determinants provides the basic tool for these proofs.

The student who has mastered the content of "Introduction to Electric Circuit Analysis" is ready for advanced circuit concepts such as steady-state analysis, Laplace transform techniques, complex frequency treatments, and the specialized equivalent circuits of electronics. It is recommended to teachers of undergraduate electrical engineers.

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Introduction to Circuit Analysis, by J. D. Cowan, Jr. and H. S. Kirschbaum

Published (1961) by Charles E. Merrill Books, Inc., 1300 Alum Creek Dr., Columbus 16, Ohio. 296 pages+ix pages+5 index pages+11 appendix pages +problems by chapter. Illus. $6\frac{1}{4}\times9\frac{1}{4}$. $10.60.

This volume introduces the reader to a unified approach to phenomena encountered in linear circuit analysis. In essence, it is by design suitable for both electrical and non-electrical undergraduate students. Whenever possible, it accentuates broad implications to derive generalized concepts.

Chapter I concerns itself with the elementary physics of a circuit and definitions of functional relations involving lumped and passive parameters. These introductory concepts are expanded upon in Chapter II to evolve the inherent nature of resistance, inductance and capacitance. Chapter III describes the choices of variables as evident from the network geometry and, in Chapter IV, these variables lead to a set of integro-differential equations from which any one of the variables can be extracted. Mathematical considerations to yield transient and steady-state solutions are dealt with in Chapters V, VI, and VII.

Inductive coupling and its manifestations are treated in Chapter VIII as well as the ideal transformer. Chapter IX considers the practical transformer and its equivalent circuit representations. The steady-state response of polyphase circuits is analyzed in Chapter X. Network theorems, analogs and duals are thoroughly covered in Chapters XI and XII as essentials to the development of broad analytic techniques. The last chapter presents a concise treatment of circuit responses to non-sinusoidal driving functions based upon the Fourier analysis.

Interested readers will find the content of this book free of errors. Significant principles are stated clearly and illustrated well. Each chapter includes a list of challenging problems.

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Singularities of Linear System Functions, by B. Gross and E. P. Braga

Published (1961) by Elsevier Publishing Co., D. Van Nostrand Co., 120 Alexander St., Princeton, N. J. 60 pages+viii pages+2 bibliography pages+27 appendix pages. Illus. 5×7½.

This monograph is devoted to a study of the physical understanding and interpretation of poles, regional and isolated essential singularities, and branch lines. The authors carefully note that this is not a book covering the general features of the theories of complex functions and integral transforms, but is largely devoted to a discussion of the singularities of the analytic functions that appear in linear system theory. They have used the field of electric circuit theory as the source of examples in dealing with these problems, although they note that through analogies the results are general to linear system theory.

The book comprises five chapters of varying lengths. These are: 1) Introduction; 2) Electromechanical Analogy; 3) Uniform Structures; 4) Non-Uniform Structures; and 5) Transients of Systems with Essential Singularities. A number of appendixes are also included.

Owing to its limited objectives, the book will be of interest to persons who are concerned with physical interpretations of the more subtle aspects of network functions. To these persons the presentation will give some insight that is generally not available, although often this is accomplished at the expense of mathematical rigor. To the casual reader it may appear too specialized for his tastes. It is a book that will appeal to persons of varied mathematical interests.

SAMUEL SEELY
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Semiconducting III-V Compounds, Vol. I, International Series of Monographs on Semiconductors, by C. Hilsun and A. C. Rose-Innes

Published (1961) by Pergamon Press, 122 East 55th St., New York 22, N. Y. 229 pages+9 index pages. Illus. 6×9. $10.00.

This book describes the semi-conducting properties of III-V compounds, often by a comparison with the semiconducting properties of silicon and germanium. The authors assume that the reader has a basic knowledge of germanium and silicon, as well as a knowledge of the fundamentals of semiconductors, such as the concept of a hole or donor impurity, K space and band structure.

The book covers various III-V compounds, which include indium antimonide, indium arsenide, indium phosphide, gallium antimonide, gallium arsenide, gallium phosphide, aluminum antimonide, and boron nitrate.

The chapter on crystal structure and binding gives a brief description of the cubic zinc-blende structure and hexagonal wurzite structure which is applied to some of the III-V compounds. Infra-red lattice absorption, width of the forbidden land, piezoelectric effects, and atomic arrangement are related to binding in a qualitative way. Herman's perturbation method, which is a semi-empirical scheme, is emphasized for the development of band structure for the III-V compounds. Individual attention is given to the band structure of the previously mentioned compounds.

The impurities and defects section is limited because it has not been possible, at least up to the present time, to compare directly doped specimens with pure material. The possible exception to this is indium antimonide. The interaction between impurities tends to cause broadened impurity bands. The limitation is a result of the preparation difficulties in the III-V compounds.

Many of the techniques used in preparing germanium and silicon can also be applied to the III-V compounds, but additional difficulties arise from the presence of two elements of very different physical properties. This book deals with this problem, and special techniques peculiar to the preparation and purification of III-V compounds are considered. A chapter is devoted to the electrical properties of the III-V compounds, and special emphasis is placed on Hall coefficient and resistivity as a function of impurity concentration and temperature. There is also a section on magnetoresistance effects and the Hall coefficient in magnetic fields. Optical properties and photo-electric effects are considered, with emphasis on such topics as absorption edges, lattice absorption, free carrier effects, recombination mechanisms, and carrier lifetimes. The final chapter on applications is limited and is merely suggestive of the many possibilities for the application of III-V compounds.

Each chapter ends with a comprehensive list of references. The book is too specialized for most text-book applications. It does not include problems, nor does it offer a close correlation with basic semiconductor theory. It could, however, be a valuable reference work for semiconductor courses in which a special emphasis on III-V compounds might be desirable. Limited use is made of analytical work involving semiconductor theories, and considerable experimental data is presented. In this area, the book includes a rather comprehensive treatment of the several hundred papers which have been written in the past ten years.

The book should be most useful to scientists who wish to acquire knowledge of III-V semiconducting compounds. It is intended for self-education and as an aid and reference work for specialists in the field; it serves this purpose excellently.

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Elements of Maser Theory, by Arthur A. Vuylsteke

Published (1960) by D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N. J. 337 pages+4 index pages+xiii pages+5 bibliography pages+15 appendix pages. Illus. 6¼×9¼. $9.50.

The work under discussion primarily represents an organized review of concepts and formalism of classical and modern physics pertinent to the theory of quantum mechanical devices, particularly microwave masers. Subjects treated in the first half of the book are the old and the new quantum theory, the statistical mechanics, and the interaction of radiation and matter. The last half is exclusively devoted to the subject of masers, including two and three level excitation, gas and paramagnetic masers, and maser noise. In general, the material is presented in a concise and thorough fashion, although on occasions the mathematical treatment is somewhat cumbersome.

It should be emphasized that, as the title may imply, this work is concerned with the physical theory of masers. The circuit aspects of masers—a very broad subject in itself—are discussed at best superficially. The book contains a very extensive, perhaps unnecessarily lengthy, list of references. Little is gained by making references to original works of Boltzmann, Jeans and Bohr.

The book appears to be intended for a class of readers relatively unfamiliar with basic theories and methods of modern physics. Thus, it is of little interest to the graduate physicist or to the worker in the field. Currently, however, graduate electrical engineers are required to familiarize themselves with physical theories fundamental to quantum mechanical devices. The book is recommended to the latter class of readers.

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Thermal Conduction in Semiconductors, by J. R. Drabble and H. G. Goldsmid

Published (1961) by Pergamon Press Ltd., 122 E. 55 St., New York 22, N. Y. 248 pages+8 index pages +ix pages+4 bibliography pages+23 appendix pages +list of symbols. Illus. 6×9. $10.00.

For those people who are not specialists in thermoelectric research and development, it might seem that the very specialized topic of thermal conduction in semiconductors would not warrant treatment in book length. This book, however, makes the valid point that the physics and mathematics one needs in order to understand heat transport in semiconductors applies to both metals and insulators. Viewed in this context, a book which adequately covers the complex field of thermal conductivity is quite relevant to today's science and technology. Unfortunately, this book does not give this adequate coverage. The present blending of the knowledge of a good experimentalist and a good theorist is poor. The experimental parts constitute an introduction to thermal conductivity tailored for those who need to use this knowledge at a practical engineering level. The details of the techniques necessary for careful measurements of and the theoretical details for the evaluation of thermal conductivity experiments are lacking. Representative, but far from complete, tables and graphs of the thermal conductivity of semiconducting materials reported in the literature are presented. The data for the better known materials such as Si, Ge, InSb PbTe, and Bi_2Te_3 are, however, well documented. The critical evaluation of these data is either absent or sketchy. The application of theory to the carefully measured materials is adequate for normal engineering needs. A study in depth of experimental results is lacking.

As a compensation for those people who want to understand the mathematical theory of transport mechanisms in detail, a very good exposition of irreversible thermodynamics, the concept of the maximum rate of entropy production, and the variational method are presented. A sound bridge between this erudite development and the experimental results is not included.

This is a book written on the two topics of experiment and theory, and these topics are written at different levels. Each of these limited treatments is well done and comprehensible. Neither treatment is sufficiently comprehensive in scope to make this book much more than another reference work in the field of thermal conductivity. One might well wish that the authors give a possible second edition a more thorough coverage and a better integration of theory and experiment.

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Computer Control Systems Technology, Cornelius T. Leondes, Ed.

Published (1961) by McGraw-Hill Book Co., Inc., 330 West 42nd Street, New York 36, N. Y. 636 pages and 13 index pages and x pages. Illus. 6¼×9¼. $16.00.

Authored by twenty-one leading figures in the theory and practice of the art, including its editor, this work is an outstandingly useful contribution to the working literature of systems engineering and operations research. Despite the number of coast-to-coast distribution of its sources, the editorial integrity of the content is remarkable. Based on a lecture series delivered at five centers of technological and scientific activity in the State of California during the spring semester of 1959, the book is organized in three main parts, namely, Computer Technology, Control Technology and Application to Complex Systems.

Part I. Computer Technology, covers in seven chapters both analogue and digital computers, uniquely and in combination, concluding with a chapter on system error analysis in computation by C. B. Thompkins.

Part II, Control Technology, in six chapters treats control systems theory, synthesis techniques, nonlinear theory, sampled-data theory, random processes and optimal control problems in discrete time systems. Salzer's chapter on sampled-data control systems theory is particularly interesting and provocative.

Part III, Applications to Complex Systems, gets down to cases on navigation, guidance and control of aerospace vehicles, air traffic control, optimalizing cruise control systems, control problems in nuclear reactors, automatic machine-tool control, and computer control in process industries. The chapter on numerical machine-tool control by Rosenberg is a veritable handbook for this field, including authentic historical as well as practically useful information for the systems designer.

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Progress in Operations Research, Vol. I, Russell L. Ackoff, Ed.

Published (1961) by John Wiley and Sons, Inc., 440 Park Ave. S., New York 16, N. Y. 489 pages+13 index pages+xii pages+2 bibliography pages. Illus. 6×9¼. $11.50.

This volume, which was planned as the initial production of a proposed ORSA review series, considers a variety of subjects fundamental to Operations Research. Each chapter is individually authored; the book therefore has both the stylistic unevenness and the personal touch to be expected from such a procedure. The first and last chapters are general in approach and attempt to deal broadly with status and prospects of the studies designated by the term "Operations Research." The intervening nine chapters are more specific, each dealing with a particular specialty.

Several of these (Chapter 2—on Decision and Value Theory; Chapter 3—on Inventory Theory; Chapter 7—on Sequencing Theory; Chapter 8—on Replacement Theory; especially Chapter 9—on Simulation; and Chapter 10—on Military Gaming) are primarily philosophical in nature, the important quantitative results being mentioned rather than developed.

Others (Chapter 4—on Mathematical Programming, Chapter 5—on Dynamic Programming, Chapter 6—on System Dynamics) are considerably more quantitative and specific in flavor.

All chapters reflect the exertions of the editorial staff to produce a reasonably accurate status report of the field, at the expense, perhaps, of depth reporting on foundations, problem areas and research in progress. A good many references to the research literature are included with each chapter.

The book suffers because ideas in an area like this become outdated so quickly, this appears to the reviewer to be a particularly serious problem in areas where computer capabilities are an important influence. For example, the developments in digitally switched analog computers promise to alter our past ideas of analog equipment usefulness in simulation problems. Again, the 7090, scarcely more than a dream to the operations researcher at the time the material in the book was written, is already being surpassed in speed by other, more advanced machines. More significant is the fact that our experience with machines with size and speed in the range of the 7090 has tended to make Monte Carlo and related procedures much more generally useful in practice than was formerly the case.

The plan and execution of the book are commendable. The articles are individually and collectively helpful in establishing the status of the field as of around 1959.

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RECENT BOOKS

Battelle Memorial Institute. *Semiconductor Abstracts, Vol. VII.* John Wiley and Sons, Inc., 440 Park Ave. S., New York 16, N. Y. $20.00.

Ceccato, Silvio, Ed. *Linguistic Analysis and Programming for Mechanical Translation.* Gordon and Breach Science Publisher, Inc., 150 Fifth Ave., New York 11, N. Y. $7.50.

Defense Systems Dept., General Electric Co. *Tables of the Individual and Cumulative Terms of Poisson Distribution.* D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N. J.

Dewitt, Nicholas. *Education and Professional Employment in the USSR.* National Science Foundation. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. $5.50.

Dushman, S. and Lafferty, J. M. *Scientific Foundations of Vacuum Technique, 2nd Edition.* John Wiley and Sons, Inc., 440 Park Ave. S., New York 16, N. Y. $19.50.

Hanssmann, Fred. *Operations Research in Production and Inventory Control.* John Wiley and Sons, Inc., 440 Park Ave. S., New York 16, N. Y. $8.95.

Hobbs, Marvin. *Fundamentals of Rockets, Missiles, and Spacecraft.* John F. Rider Publisher, Inc., 116 W. 14th St., New York 11, N. Y. $8.95.

Jensen, J., Townsend, G. E., Jr., and Kraft, J. D. *Design Guide to Orbital Flight.* McGraw-Hill Book Co., 330 West 42nd St., New York 36, N. Y. $17.50.

Kibbee, J. M., Craft, C. J., and Nanus, Burt. *Management Games.* Reinhold Publishing Corp., 430 Park Ave., New York 22, N. Y. $10.00.

Kuo, Benjamin C. *Automatic Control Systems.* Prentice-Hall, Inc., Englewood Cliffs, N. J. $16.00.

Macko, Stanley. *Satellite Tracking.* John F. Rider Publisher, Inc., 116 W. 14th St., New York 11, N. Y. $5.50.

Overholt, John, Ed. *First War Gaming Symposium Proceedings.* Washington Operations Research Council, 9120 Kirkdale Rd., Bethesda, Md. $2.00.

Riordan, John. *Stochastic Service Systems.* John Wiley and Sons, Inc., 440 Park Ave. S., New York 16, N. Y. $6.75.

Abstracts of IRE Transactions

The following issues of TRANSACTIONS have recently been published, and are now available from the Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, N. Y. at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.

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Antennas and Propagation

VOL. AP-10, NO. 2, MARCH, 1962

Antennas and Data Processing—R. N. Bracewell (p. 108)

Directional properties of a complete radiometer are becoming more dependent on the electronics combined with the antenna, so that techniques of linear signal analysis are becoming part of antenna design.

Multiple Target Response of Data-Processing Antennas—M. E. Pedinoff and A. A. Ksienski (p. 112)

The response of nonlinear data-processing antenna arrays are evaluated for multiple target situations. These situations involve targets of various relative strengths and angular separations. The evaluation is carried out both analytically and graphically, and the results obtained are compared to the performance of a linear array.

On the Mapping of Extended Sources with Nonlinear Correlation Antennas—C. J. Drane and G. B. Parrent, Jr. (p. 126)

In this paper nonlinear correlation antennas are re-examined in terms of coherence theory. Particular emphasis is given to an antenna system consisting of the correlation of the outputs of two arbitrary antennas. It is shown that such a system operates in a linear fashion for an extended incoherent source. In fact, a flat spatial frequency response for this system can be obtained when, in particular, one antenna is a continuous array with a uniformly illuminated aperture, while the other is a simple interferometer.

Array Factors with Nonuniform Spacing Parameter—A. L. Maffett (p. 131)

An algorithm is formulated to describe the construction of arrays whose individual antenna elements are to be distributed nonuniformly over an aperture. From the distribution to which the algorithm is equivalent, a distribution of array factor values is inferred. It is also shown how the individual array factor values may be statistically described when the element placement is statistically described.

An array of antenna elements can be nonuniformly distributed so as to produce an array factor with a single major lobe from one-fourth the elements required by a uniform distribution at a sacrifice of 5 db in sidelobe level and no sacrifice in main beamwidth.

Linear Arrays with Variable Interelement Spacings—M. G. Andreasen (p. 137)

Optimum broadside arrays with constant spacings, *i.e.*, Dolph-Tchebycheff arrays, use relatively many elements and are often difficult to realize in practice due to mutual coupling effects. To overcome these disadvantages a variety of arrays with widely and variably spaced elements have been designed using both analog and digital computer techniques. These arrays all have many fewer elements than Dolph-Tchebycheff arrays with the same beamwidth and sidelobe level.

One of the arrays designed has 21 elements and is 76 wavelengths long when used as a broadside array. The 3-db beamwidth is 0.74 degree, the sidelobe level -7.4 db. The array has perfect steerability in a 1.8:1 bandwidth with no interelement spacing smaller than one-half wavelength in this band. A Dolph-Tchebycheff array with the same beamwidth and sidelobe level uses 53 elements, and the steerability is not perfect even at a single frequency.

Theory of Frequency Scanning of Antennas—A. Ishimaru and H. S. Tuan (p. 144)

This paper presents the theory of 180° scanning for a linear array and Tchebycheff array by frequency variation and discusses the relationships between the linear array theory and the ω-β diagram of periodic structures. Each element is excited by a slow-wave structure which is either nondispersive or dispersive. At a center frequency, the spacing is an integral multiple of guide wave-length $M\lambda$. It is shown that this is in fact the $-M$th space harmonic in the so-called forbidden region, and all the other harmonics are slow. For a given frequency range, the necessary phase velocity and other parameters are determined in order to obtain 180° scanning without causing other main beams, and the example is carried out for the X-band frequency range.

Closed Form Analysis for the Radiation Pattern of the Modulated Antenna—A. Ishimaru and G. D. Bernard (p. 151)

In this paper a new method of analysis for the far zone radiation pattern of the antenna with modulated aperture field is developed. The result of the conventional method is in terms of an infinite series of Bessel and sin u/u functions and is not suitable for the prediction of sidelobes, beamwidth and the effect of various parameters. The purpose of our new method is to avoid the above disadvantages by writing the radiation pattern in simple closed form involving only the Anger function times a simple periodic modifying function. Using this method, the relationship between aperture field parameters and the radiation pattern is clear. The type of modulation considered is cosinusoidal amplitude across the aperture and sinusoidal phase modulation across the aperture.

The case of constant amplitude is discussed in detail and is applied to the modulated slow wave structure. The end of the visible region is chosen at the second peak of the total radiation function and the endfire pattern is considered in detail in terms of fundamental slow wave speed, and the magnitude, sign, and frequency of the phase modulation.

Conditions are derived for excitation phase velocity, magnitude of phase modulation and the tilted main beam.

Sandwich-Wire Antenna—Kun-Mu Chen (p. 159)

An approximate theoretical study of a sandwich-wire antenna is presented. The two outer conductors are in parallel and the center conductor is bent into triangular form with a period equal to the wavelength. The attenuation constant is obtained. The radiation pattern of an array consisting of a number of sandwich-wire antennas is evaluated. The theoretical resulsts are compared with the existing experimental data.

Elliptically Polarized Leaky-Wave Array—W. J. Getsinger (p. 165)

This paper describes the application of Bethe's small-aperture theory and leaky-wave antenna theory to the design of planar arrays of rectangular waveguides radiating through small apertures arranged periodically in their broad walls. Such arrays can be designed to have any polarization, including circular, by suitable selection of the shape and orientation of the small apertures. These arrays have narrow beamwidths, and scan with frequency in a plane normal to the broad walls of the waveguides.

A circularly polarized array at X-band was designed, and a single-waveguide section of it built to test the practicality of the design.

Digital Computation of the Mutual Impedance Between Thin Dipoles—H. C. Baker and A. H. LaGrone (p. 172)

This paper presents a method for computing the mutual impedance between any two linear center-fed antennas having sinusoidal current distributions. This method, which is very conductive to digital computer application, is not limited in terms of the lengths or of the relative geometrical configuration of the antennas involved. The method has been used to com-

pute data which have been checked with both published and experimental data for various parallel, echelon, and skew cases. The results of many of these calculations are given.

An Antenna Array of Longitudinally-Slotted Dielectric-Loaded Waveguides—E. D. Sharp and E. M. T. Jones (p. 179)

This paper describes the design and measured performance of an antenna made up of an array of dielectric-loaded rectangular waveguides with common narrow walls. Longitudinal slots are cut in the center of each broad wall. The preferred form of this antenna uses a slab of dielectric placed over all the slots, although it can operate when dielectric is placed within each guide. An approximate theory is discussed, and empirical design data are presented from which an experimental model of this antenna is designed. Empirical data are also given for cases in which dielectric is placed inside the waveguides. The radiated H field from this antenna is parallel to the antenna aperture, and the main beam is directed up from the aperture at an angle equal to the arc cosine of the velocity of light divided by the slotted-waveguide phase velocity.

An experimental antenna, constructed using standard 0.900- by 0.400 in waveguide, had an aperture 9 in wide by 20 in long. The antenna was fed from a hog horn, which yielded an approximately sinusoidal H plane illumination over the 9-in aperture width. The slot width was varied over the 20 in length to obtain a Taylor aperture distribution yielding a theoretical radiation pattern with -25.5-db E-plane sidelobes and with a 5.4° beamwidth. At the design frequency of 10 kMc, the E-plane and H-plane beamwidths were 5.4 and 8.0 degrees, respectively, and the E-plane and H-plane first sidelobe levels were -22.0 db and -23 db, respectively. Good radiation patterns were obtained from 8 to 11 kMc.

An Analysis of Polarization Variation and Its Application to Circularly-Polarized Radiators—T. S. Chu and R. G. Kouyoumjian (p. 188)

Three general theorems giving conditions for a radiating system to exhibit stationary polarization, stationary gain and the coincidence of stationary polarization and gain in a prescribed direction are presented. A necessary and sufficient condition for the polarization invariance of a circularly-polarized radiator is derived. The theorems are applied to a number of circularly-polarized sources and antennas which are broadly directional. The polarization change with respect to aspect for the radiators possessing a direction of stationary polarization at the pattern maximum is small; however, in the case of the helix, whose pattern maximum is not in the direction of stationary polarization, the change is comparatively large. The polarization variation which occurs when these antennas are used as the elements of an array or the primary feed of a reflector is considered.

An Electronic Method for Steering the Beam and Polarization of HF Antennas—G. Vogt (p. 193)

Steerable antenna arrays in the HF range differ from these employed at higher frequencies in that they are enormous in size. A wide variety of phasing methods to form the desired steerable antenna pattern have been designed or proposed. These systems, which feature a common phasing center for all elements of the array, require expensive cabling from the individual antenna element to the phasing center. An electronic phasing system which operates by remote control would allow the distribution of the phasing matrix over the entire array, and would not only bring about substantial cable savings, but would also increase the flexibility of the antenna design by the introduction of novel design parameters. A description is given of such a system which consists of continuously-controlled phase shifters, generators to control the phase shifters, and an analog computing method to determine the correct phase shifts for the indivual elements. This steering method, developed for scanning and positioning the beam of an antenna array in the direction of an incident ray, can also be applied to adjust the polarization plane of the antenna. By combining the two systems, further improvements in long range radio communications can be expected.

Effect of Obstacle Profile on Knife-Edge Diffraction—M. P. Bachynski and M. G. Kingsmill (p. 201)

Experimental studies on the effects of the profile of a dominant obstacle on the diffraction of electromagnetic waves are described. A comparison of the distribution of diffracted power behind triangular (both symmetrical and nonsymmetrical) knife edges and semicircular knife edges shows some important practical features. In contrast to the case of a horizontal obstacle, the transverse profile of the triangular obstacle determines the optimum receiving site and relatively small changes in receiver location can result in substantial changes in received power. On the other hand, the semicircular knife edge can be adequately described in terms of a rectangular (180°) knife edge. In no case is an effect on the far field due to the polarization of the incident fields apparent.

Electromagnetic Radiation from a Cylindrically Capped Bi-Wedge—M. A. Plonus (p. 206)

The cylindrically capped bi-wedge is an arrangement of two perfectly conducting wedges, apex to apex and exactly opposing; it is truncated by a cylinder whose axis is the apex of the biwedge. A line source at the apex excites this geometry. To find the radiation properties of this configuration the corresponding boundary-value problem is solved.

Truncating the bi-wedge by a cylinder defines two regions—the interior and the exterior. The fields in the interior and exterior region are given by appropriate series expansions which are solutions to Maxwell's equations. A relationship between the coefficients of the two fields is obtained when the fields are matched across the aperture. A set of infinite simultaneous equations is generated. These can be solved for the coefficients to which special summation techniques have been applied to make a truncation of the infinite matrix valid. The radiated filed of a bi-wedge is then expressed as a series with unknown coefficients. These can now be calculated by solving a set of finite simultaneous equations. A bi-wedge in the resonance region was chosen to illustrate this procedure. The computations for $ka=\pi/2$ were performed and the far-field radiation patterns plotted for various wedge angles. The limiting case of the Rayleigh region, the thin bi-wedge, and the bi-wedge when the angle θ_0 approaches $\pi/2$ are then analyzed. It is found that for the thin and the very thick bi-wedge the matrix decouples, and the field can be given exactly for these two limiting cases. Furthermore, it was found that the simple formulas of the two limiting cases could be extended to give usable results for other angles, thereby avoiding a solution of the infinite matrix.

Communications (p. 211)
Contributors (p. 217)

Audio

Vol. AU-10, No. 1, January–February, 1962

The Editor's Corner—M. Camras (p. 1)
PGA News—H. C. Hardy (p. 2)

Current Research in Sound—V. Salmon (p. 5)

Sounds in industry may go unheard by the ear, but they are all-important to "listening" machines, compounds, and processes. Already with sound we can test, mix, measure, clean, drill, and control. And research indicates broad new applications in the tomorrow.

Syllable Analyzer, Coder and Synthesizer for the Transmission of Speech—H. F. Olson and H. Belar (p. 111)

The analysis of speech by machine, the transmission of the coded message and the synthesis of speech from the code offer many advantages. For instance, if it is desired to transmit only "what" is spoken and not "how" it was spoken, very great savings in channel capacity to transmit information can be made. The digital form of the message permits more secure coding and decoding for secrecy. Work done at the RCA Laboratories on phonetic typewriters, machines that type in response to words spoken into a microphone, has shown that the transmission of speech analyzer output and synthesis of speech therefrom is feasibe when performed by units of speech of the order of a syllable. Smaller phonetic entities, phonemes or speech sounds, cannot always be recognized by machine or even by ear without the knowledge of adjoining sounds. This information is always available when the analysis proceeds by syllables. Feasibility studies have also shown that intelligible speech can be synthesized from prerecorded syllables.

Phasor Analysis of Some Stereophonic Phenomena—B. B. Bauer (p. 18)

An improved understanding of some stereophonic phenomena may be obtained by use of acoustical pressure phasors to portray sound pressure at the ears of the observer. With the help of phasors, it is possible to expand and modify certain conclusions of previous observers and to validate some previously unpublished observations: a stereophonic "law of sines" is derived. The existence and location of the "out-of-bounds" stereophonic image is analyzed and verified. The "allowed maximum out-of-phase ratio" is derived, together with the observation that this maximum is exceeded by certain microphone arrays. The motion and elevation of the center image in stereophonic reproduction is observed and explained.

The Hamograph—A New Amplitude Rhythm Control Device for the Production of Electronic Music—M. Schaeffer (p. 22)

The Hamograph was designed and built to fulfill the need for a practical and relatively inexpensive means for controlling the rhythm and dynamic envelope of raw electronic sounds, as a tool for the electronic music composer. The machine consists of control loops of variable speed, which carry the rhythmic and envelope message in the form of conductive contours read by a series of contacts of graduated resistance, which in turn modulate the signal voltage. Any type of sound may be subjected to such control which results in a wide variety of musical textures and melodies. Corrections can be made easily, and the number of splices required for a total electronic composition is materially reduced.

Correspondence (p. 25)
Contributors (p. 28)

Automatic Control

Vol. AC-7, No. 2, March, 1962

On Minimum of Maximum Expected Deviation from an Unstable Equilibrium Position of a Randomly Perturbed Control System—M. Aoki (p. 1)

A Non-Linear Analysis Technique for an On-Off Servo with Velocity Inputs—H. R. Farrah (p. 13)

Optimum transient response can theoretically be obtained with a servo system operated in an on-off mode. Although phase plane techniques can produce an optimum system for positional inputs, it is shown that a phase plane analysis is invalid for velocity inputs for a type 1 control servo. A novel approach to the problem is presented which permits an optimum switching procedure to be obtained for velocity inputs, while validity is retained for positional inputs. The resulting system has the properties that the steady state error for both velocity and positional inputs is zero, and no more than two switching cycles are ever needed to return the error to zero.

Synthesis of High-Order Nonlinear Control Systems with Ramp Input—C. N. Shen (p. 22)

Unsymmetrical half periods exist in a system with static and kinetic dry friction. The time duration under kinetic and viscous friction is much shorter than that under static friction alone. The condition of sustained oscillation is formulated and determined by a modified describing function method. The accuracy of this method is evaluated by comparison to an exact analysis.

A Phase Space Investigation of Bi-Stable Systems by Means of Vectors—R. V. Halstenberg (p. 38)

An investigation is made to determine the conditions under which a third order system with a bi-stable element will maintain a high frequency oscillation rather than exhibit simple relay switching. A criterion is developed in general terms. The study is made in phase space and vectors are used to determine the direction in which the trajectory intersects the switching plane. The appendix contains an example wherein the criterion is applied to a specific system and the results compared with computer data.

Synchronous Networks—G. Weiss (p. 45)

"Synchronous" networks, also called "chopper" networks and "commutated" networks, consist of passive elements plus driven switches or choppers. R-C chopper networks have been used occasionally as compensating networks in A-C servos. Their main advantage is a response independent of carrier frequency variation, and freedom from zero drift. Their main disadvantage is noise output in the form of harmonics of the carrier. In this paper a rigorous analysis of an idealized R-C loaded chopper is presented. It is shown that the main component of the response is indeed independent of the carrier frequency.

Analysis and Synthesis of Dynamic Performance of Industrial Organizations—The Application of Feedback Control Techniques to Organizational Systems—R. B. Wilcox (p. 55)

In this paper a method is described for evaluating the dynamic performance of the operation of an organization. It is shown that the performance response of past efforts can be expressed mathematically by means of performance operators leading to the development of a mathematical model of the process of industrial operations. This paper considers the operation of an engineering organization as a dynamic system and shows that the organization may be treated as a feedback control system with all control techniques of analysis and synthesis applied.

Control Concepts for Nuclear Ramjet Reactors—R. E. Finnigan (p. 68)

Stability and Control of Nuclear Rocket Propulsion—R. R. Mohler (p. 86)

A systems treatment of the dynamic behavior of nuclear rocket propulsion systems is presented. This simplified analysis does represent the basic ideas of more detailed computer studies. Nuclear reactor systems for space propulsion are much faster than conventional reactor systems which complicates the controls problem. (The dynamics of chemical systems have been simpler in nature due to their speed of response.) One attractive solution, which uses the propellant reactivity, is discussed.

Integral Transforms for Algebraic Analysis and Design of a Class of Linear-Variable and Adaptive Control Systems—G. W. Johnson and F. G. Kilmer (p. 97)

Regression Techniques in Multivariate Adaptive Control Systems—A. B. Bishop (p. 107)

A control system is proposed which utilizes a multiple regression technique for optimal control of a multivariate nonstationary process. The concept underlying this system is the basing of each set of control actions on a current statistical description of the process, so that the adjustments performed will cause control of the output in an efficient manner. Adjustments are made to occur at discrete intervals. Descriptions of the applicable statistics and the computations required are presented, and the problem of choosing decision rules to relate control actions to process statistics is discussed. Several decision rules of practical importance are examined.

Optimum Design of Passive-Adaptive, Linear Feedback Systems with Varying Plants—P. E. Fleischer (p. 117)

In designing a feedback control system involving a variable (or incompletely known) plant the prime consideration, besides obtaining a satisfactory transfer function, is to specify a system which is insensitive to plant variations Some procedures for obtaining insensitive designs have been described in the literature, but they all result in systems having large open loop bandwidths. In the presence of instrument noise such systems would tend to produce an excessive noise output. In this paper a minimization is carried out, where the conflicting requirements of small sensitivity to plant variations and insensitivity to instrument noise are satisfied simultaneously. The solution is approximate, but can be justified in most physical situations. A method for iterating the solution is also described.

Adaptive Control Through Sinusoidal Response—K. C. Smith (p. 129)

An investigation has been made in the application of sinusoidal techniques to adaptive feedback control systems. The adaptive feature of this approach is an automatic gain control. These systems contain two loops: a basic or primary control loop and an adaptive control loop. The forward-path gain of the basic loop is adjusted by the adaptive loop. A sine wave test signal is added continuously to the basic loop input and to a model. The phase shift or the amplitude of the basic loop output is measured by an adaptive computer which adjusts the forward-path gain in an attempt to hold the measured amplitude or phase-shift constant.

This paper contains derivations of the adaptive loop response to changes in the process gain factor for several cases. Some of the considerations pertaining to the design of the adaptive control loop are also given.

Optimizing Control with Process-Dynamics Identification—P. Eykhoff and O. J. M. Smith (p. 140)

The meaning of the terms process identification, adaptive and optimizing control is indicated. The basic difference between these types of control and the ordinary ones is the need for a "learning process." Using multiplication plus integration as the simplest possible type of "learning," simple schemes are obtained in which sinusoidals or random fluctuations may be used as test signals.

A more detailed study and an analog simulation have been made of such an optimizing system. This one is free from the defects of formerly proposed systems, i.e.:

—the detrimental effects of system dynamics on the optimizing control action,

—the loop gain changes and even instability of the optimalizing control loop when the process dynamics change with time.

This has been achieved by introducing a model of the process dynamics, the parameter(s) of which are controlled by an identifying-control loop.

A typical value for the convergence speed towards the optimum of the optimizing control can be given as follows: using a sinusoidal test signal, the transient for a step-disturbance is approximately of the form $\epsilon^{-t/\tau}$ where the value of τ corresponds with three periods of the test signal used.

Although the system is nonlinear and time varying, some analytical results have been obtained which check the computer results. The ideas presented can be extended to more-dimensional optimization and more-parameter identification.

Component Parts

Vol. CP-9, No. 1, March, 1962

Information for Authors (p. 1)

Who's Who in PGCP—L. Podolsky (p. 2)

Status of Microminiaturization—E. F. Horsey and P. J. Franklin (p. 3)

The status of microminiaturization is summarized under the following three headings: 1) assembly of pretested conventional or specially designed component parts, 2) printing or vapor deposition of multicomponent assemblies on flat insulating substrates, and 3) preparation of complete circuits from a solid block of semiconductor material.

Under the first heading, assembly of parts in three-dimensional (3-D) soldered structures, in 3-D welded structures, in imitation 2-D-type structures, and in structures of disciplined geometry is briefly described. The latter structures now include not only the Micro-module but also new pelletized parts.

Under the second heading, the original 2-D thin-film type of construction is briefly summarized and then the evolution of this system into experimental circuits containing all thin-film passive parts is shown. The logical next step, preparation of circuits containing thin-film active as well as passive parts, is in even earlier stages of research.

Under the third heading, new developments in integrated and functional circuits are presented. The trend of current work points to the conclusion that equipment available commercially in the next decade will probably take the form of hybrid structures comprising both individually fabricated parts, and single-process parts arrays, all mounted or processed onto an insulating substrate.

Solid-State Physical Phenomena and Effects—Part II—E. J. Scheibner (p. 19)

This is the second in a series of four articles designed to provide ready information to workers in the field of molecular electronics. Fifteen additional solid-state phenomena and physical effects are described. Each of these phenomena belongs to a group whose effects depend either upon the transport of electrons and holes or upon the band structure of the material.

Negative-Impedance Converters—I. M. Horowitz (p. 33)

This paper is devoted to the device properties of the negative-impedance converter (NIC), the derivation of potential NIC circuits and their compensation in order to achieve an exact NIC. The behavior of the NIC as a function of frequency and means of extending its

useful frequency range are presented. Attention is also devoted to the sensitivity of the NIC to variations in active and passive parameter values and to means of reducing the sensitivity.

Very-Wide-Band Impedance-Matching Networks—T. R. O'Meara (p. 38)

A method is described for combining two transformers and supplementary network elements in a class of wideband impedance-matching networks whose over-all bandwidth in octaves is essentially the sum of those of the two component transformers. One transformer transmits the high-frequency portion of the required operating range and is relieved of the low-frequency requirements, while the other transformer transmits the complementary low-frequency range. Thus the composite network characteristic is all-pass over a very large frequency band.

The basic network has a group-delay characteristic which is nonflat over the band-pass region; it is shown how additional all-pass sections may improve this characteristic.

An experimental coupling network exhibits an extension in frequency response by about a factor of 40 over that obtainable with the low-frequency transformer alone.

The Photoreed—A New Versatile Frequency-Sensitive Control Element—F. H. Inderwiesen, Jr. (pp. 44)

The photoreed performs the functions of resonant reed relays and tuning-fork filters or oscillators. The photoreed evolved from combining resonant reed and photoelectric principles, *i.e.*, the action of light on a suitable photosensor to regulate the current through the photosensor and its load circuit. The photosensor is exposed to the light when the reed, acting as a shutter, vibrates. No electrical contacts are required. The design criteria and performance data of the photoreed are discussed for each circuit function. The photoreed has superior performance, flexibility and versatility when compared with conventional resonant reed relays.

Contributors (p. 50)

Electron Devices

Vol. ED-9, No. 1, January, 1962

The Design and Performance of a Magnetron-Injection Gun—G. S. Kino and N. J. Taylor (p. 1)

The space-charge flow solutions described by Kino and others in connection with the crossed-field carcinotron gun can be generalized to form the basis of a magnetron-injection gun design suitable for the production of hollow electron beams. In the first part of the paper this generalization is described. From the resulting flow it is possible to determine by an approximate method the electrodes to produce a gun of desired perveance with nearly uniform current density at the cathode. This technique has been used to design guns having ratios of cathode length to a diameter considerably greater than unity. The close agreement between the results obtained on several experimental guns and the theoretical predictions is described, along with the effect of departures from the prescribed fields given by the design method.

Conservation Principles for Plasmas and Relativistic Electron Beams—A. Bers and P. Penfield, Jr. (p. 12)

Many useful conservation theorems are derived for relativistic electron beams and anisotropic plasmas. All these theorems are valid for confined-flow and irrotational-flow devices, and cold, collisionless plasmas. All the theorems are derived in a similar way, and a generalization of this method, using linear operators, is given.

Among the power theorems discussed are: Tonks' theorem, the instantaneous and sinusoidal small-signal theorems, the energy theorem, a large-disturbance theorem, the Manley-Rowe formulas, an ac power theorem, and a cross-correlation theorem. Contributions to power and energy from surface waves are included. Allowing for relativistic flow and writing all equations in the laboratory frame does not significantly complicate the theorems, and in fact clarifies them somewhat.

Many simple applications are discussed, although not in detail. Among these are: small-signal energy, power, and passivity; energy velocity in electron beam and plasma waveguides; and a conservation theorem for multiple electron beams and electron beam-plasma interactions.

A Proposed Harmonic Generator Based on Cyclotron Waves—K. Blötekjaer (p. 27)

A cyclotron wave on a rectilinear filamentary beam can interact with a TE circuit mode of cylindrical symmetry propagating in synchronism with the beam. The interaction results in a periodic variation of the cyclotron transit angle of the electrons, causing a type of circumferential bunching which gives rise to high harmonic content. Provided the RF-field is adjusted to maximize a certain harmonic, its output power increases approximately as the square root of the harmonic number.

The bunching is simply a redistribution of the relative positions of the various electrons constituting the original beam, and requires no supply of energy. All power delivered by the generator is therefore dissipated in the RF structure itself.

The interaction mechanism is analyzed in detail, using two different approaches leading to the same final results. One is based on a wave description, the other considers the motion of the individual electrons. Possible applications for harmonic generation of high frequencies are discussed.

A Simplified Method for Calculating Klystron Performance—W. J. Pohl (p. 32)

Designers of multicavity klystrons, faced with decisions in connection with the drift length/gain/efficiency compromise, can find theoretical treatment in an alarming variety of literature based both on the space-charge wave and the ballistic-electron-bunching theory. The only papers which effectively combine both theories are those of Webber [1], [2], in which a large number of curves representing considerable diversity of conditions have been computed.

It has been found that, at the cost of a small error, a rearrangement of these results leads to useful universal curves (Fig. 1) enabling rapid decision making with regard to the efficiency/gain/drift length compromise, in most situations. Gain calculations using Fig. 2 have given good agreement with practical results.

Why a Circuit Sever Affects Traveling-Wave Tube Efficiency—A. W. Scott (p. 35)

The effect of a circuit sever on traveling-wave amplifier efficiency has been calculated from the large-signal traveling-wave tube equations. Measurements made on high-power traveling-wave amplifiers, which utilize a severed coupled-cavity interaction circuit, have confirmed the calculated results. The results show that a traveling-wave amplifier with $C=0.1$ and $QC=0.25$ must have 26 db or more growing-wave small-signal gain beyond the sever to obtain the maximum theoretical efficiency. If the growing-wave gain is less than this value, efficiency is reduced; for example, if the gain is 4 db less, the efficiency is reduced by one half. The mechanism which causes this reduction of saturated output power can be understood from the computed electron distribution in phase and velocity. From these phase-velocity diagrams, the degradation in efficiency is seen to be caused by the debunching of the beam by space-charge forces in the region between the sever and the point where the microwave signal builds up to the value it previously reached before the sever. Further study of the computer results shows that the loss in efficiency caused by insufficient gain beyond the sever cannot be made up by depressed collector operation, and that the use of overvoltage to obtain increased efficiency in a severed tube may not be effective because of the resulting reduction in gain that overvoltaging causes.

A Large-Signal Analysis of Beam-Type Crossed-Field Traveling-Wave Tubes—J. W. Sedin (p. 41)

The equations describing a two-dimensional model of a beam-type crossed-field device are presented in a form adaptable to numerical computations. A method of computing the space-charge forces similar to that used by Tien, Walker, and Wolontis in describing the ordinary traveling-wave tube is outlined and the difficulties associated with this method are pointed out. Numerical results covering the interaction of a thin beam with a backward or a forward wave are presented for a variety of space-charge conditions. Space-charge effects reduce the large-signal gain of a backward-wave amplifier; it appears that 70 per cent conversion of available potential energy to RF energy would be excellent efficiency. Space-charge fields appear to have little influence on forward-wave interaction. For either forward- or backward-wave interaction, the computations indicate that a large fraction of the beam current is collected on a very short length of circuit, thus placing a limitation on the average power capabilities of such a crossed-field device.

Slow-Wave Structures for M-Type Devices—S. P. Yu and P. N. Hess (p. 51)

M-type devices such as magnetron oscillators, magnetron amplifiers and backward-wave oscillators always contain a sole plate to provide the static electric field which, together with a transverse static magnetic field, provides electron focusing. The sole plate unavoidably becomes part of the RF structure. It is the purpose of this paper to show the effect of the sole plate on the RF characteristics of the more common slow-wave structures. The results of the study indicate that no slow-wave structure containing a sole plate can be truly a backward-wave structure. The fundamental space harmonic must contain a region wherein the phase and group velocities are of the same sign.

These results are predicted by a field analysis of the uniform-vane, strapped magnetron anode system. Such an analysis is made possible by two simplifying assumptions. The first assumption is that the interaction space between anode and sole can be replaced by an equivalent linear structure. In this way, the derived expressions for admittance become infinite series of exponential functions rather than infinite series of untabulated higher order Bessel functions. The second assumption is that the fields peculiar to the straps can be described by TEM waves. This assumption allows one to formulate a strap admittance which is in parallel with the admittance of the interaction space and the side cavity. The resultant dispersion equation can be solved graphically for the frequency-phase shift characteristic of the composite system.

This analysis predicts that the straps may be either capacitive or inductive depending upon mode number, frequency and geometry. It shows that the frequency-phase shift characteristic is not simply derivable from the unstrapped anode system by the addition of a constant phase shift. It shows further that the fundamental space harmonic must contain a region wherein the phase and group velocities are of the same sign, *i.e.*, the anode system is

not, and cannot be, a simple backward-wave structure.

These results are verified in detail by a careful and complete experimental study on a standard strapped magnetron anode structure. They are further verified by a second experimental study of the very common interdigital line structure.

A Traveling-Wave Description of Distributed Interaction Klystrons—H. Golde (p. 57)

This paper presents an analysis of the distributed interaction klystron using a simplified traveling-wave approach. The coupled-mode theory is used under the assumption that the behavior of the device can be adequately described by the interaction of the slow space-charge wave with a traveling circuit wave. It is shown that the description is equivalent to the klystron approach previously used to analyze the device.

Electron Ray Tracing by Means of Resistor Network and Digital Computer—J. R. Hechtel (p. 62)

The problem of calculating electron trajectories in an electrostatic field is solved in two steps. First, the potential distribution for a given electrode configuration is found by means of a high precision resistor network. The second step requires a series of numerical calculations using the above potential values to determine the electron trajectories. All mathematical operations have been programmed for an IBM 709 digital computer.

Three different mathematical methods are presented and compared. To check their accuracy test problems involving simple electrode configurations, for which the trajectories can be calculated analytically, were used. The error of a trajectory is defined by δ/l, where δ is the maximum transverse deviation of a trajectory from its correct position and l is the length of the trajectory. Using the most accurate of the three methods for an electron in a homogeneous electric field between parallel planes the average error was 1.3×10^{-4}. With the electric field between concentric spheres the average error was 4×10^{-3}. The method of ray tracing described can be used for two-dimensional (x, y) and axially symmetric (r, z) fields. Space charge and magnetic fields can be taken into account. The time for calculating one trajectory over the whole length of the resistor network (50 units) is approximately 25 s.

Helix Couplers for Linear-Beam Devices—C. Yeh (p. 69)

In this paper the interaction between electron beams and coupled helices is studied and generalized to include the effects of 1) space charge QC; 2) finite circuit loss d; 3) finite values of gain parameter C; 4) an unrestricted coupling parameter k, and 5) the effect of having a large positive value of the velocity parameter b such that the propagation constants are purely imaginary. A general determinantal equation including all these factors is derived from the coupled-circuit equations and the stream equation. Curves of the propagation constants for a variety of operating parameters are shown. Attention is called to the fact that a region of growing wave is found for large positive b for extremely tight coupling. The extent to which the "growing-wave island" is affected by the various operating parameters is also illustrated. Equations for the outer and inner helix r-f voltage are derived and from which curves of the propagating r-f powers along the helics are computed and plotted. Positions for maximum transfer of energy between the helices can be deduced and the extent to which they are affected by the various parameters is discussed.

Distribution of Recombination Current in Emitter-Base Junctions of Silicon Transistors—P. J. Coppen and W. T. Matzen (p. 75)

Sah, Noyce and Shockley have attributed the decrease in the current gain of silicon transistors to recombination in the space-charge region of the emitter-base junction. It is suggested that for oxide-masked diffused structures the space-charge recombination current is concentrated at the junction periphery at or just under the surface. An analysis is presented which shows that measurements of the base current of transistor structures with two base contracts, as a function of voltage applied between the two base contacts, may be used to distinguish between recombination current which is concentrated at or near the surface periphery of the junction space-charge region, and recombination current distributed over the area of the junction. For the diffused structures examined, it is shown experimentally that the recombination takes place mainly at or near the junction surface periphery.

A Diffused Field Effect Current Limiter—H. Lawrence (p. 82)

Following the development of the cut channel field effect current limiter by Warner, *et al.*[1] an all-diffused device was designed and fabricated. This paper describes the design parameters as well as the critical fabrication procedures and control limits that were found necessary in order to prepare satisfactory devices.

The current limiters were prepared from 3-mil thick slices of 50 ohm-cm, n-type silicon into which 1-mil thick gates were diffused. It is evident from the data that the tolerances for reproducibility of electrical characteristics fall within the expected variations due to diffusion control and parallel polishing of the sample if the background resistivity remains constant.

However, because of the many thermal processing steps required in the fabrication procedure, variations occur in the effective impurity content in the high resistivity material.

It is seen that the dependence of the electrical behavior of the devices on these variations is critical.

The Tunneling *P-N* Junction—R. L. Longini (p. 88)

The tunneling probablity in an Esaki diode is very much dependent on the electric field strength which is itself dependent on the local fluctuations of ion concentration. The fluctuation of depletion layer thickness due to randomness of ion position is calculated. It is shown that most of the tunneling current is carried by only a small fraction of the total area.

Effect of Surface Recombination and Channel on *P-N* Junction and Transistor Characteristics—Chih-Tang Sah (p. 94)

The current flowing in a semiconductor junction may be divided into four components according to the location of the recombination and generation of electrons and holes. These are: 1) the bulk recombination-generation or the diffusion current, 2) the bulk recombination-generation current in the transition region, 3) the surface recombination-generation current in the transition region, and 4) the surface channel current. The current-voltage relationship for these four current components may be approximated by $I=I_s \exp(qV/mkT)$, if $V>4kT/q$. Analysis shows that the reciprocal slope m for the current components 1) to 3) lies between 1 and 2, while for the surface channel current component 4) m is greater than 2 for silicon junctions and may be more than 4 for large channels. The theoretical expressions for these four current components are tested with extensive experimental data taken on silicon junctions and found to account for all of the observed current-voltage characteristics. The importance of surface recombinations and surface channels on the current gain of silicon transistor is also demonstrated experimentally. The experimental data are in accord with the theoretical prediction based on the transistor current equations which include the carrier recombination in the emitter junction and the carrier generation in the collector junction.

Program of Meeting (p. 109)
Contributors (p. 120)

Human Factors in Electronics

Vol. HFE-3, No. 1, March, 1962

Guest Editorial—R. R. Riesz (p. 3)
Arms Control—H. K. Weiss (p. 4)

This paper reviews some of the proposals for arms control which have been in the past. It is shown that although some progress has been made in indicating means for reducing the effects of some of the peripheral causes of war, no plausible solution has yet been discovered for the central problem. Even the definition of the objectives which should be set for an arms control process is obscure. A brief review of the statistical incidence of war by magnitude and severity indicates that the trend to large wars of increasing severity has existed for almost a hundred years, culminating in the availability of nuclear weapons. A recognition of the possible consequences of this trend, intensified by the knowledge of the capabilities of nuclear weapons, has produced the current growing effort to understand the problem and to find acceptable arms controls.

Visual Acuity Under Blue Illumination—R. T. Mitchell and R. R. Mitchell (p. 14)

Short-wavelengths illuminants of a blue color are used in lighting SAGE and other military operations rooms in which dim cathode-ray tubes are the primary visual source of information. This study investigated the effect of such lighting on the operator's visual acuity in the performance of secondary visual tasks.

Acuity was compared under white and blue illuminations of equal intensities. At a viewing distance of 13 inches no difference in performance was found. In two experiments at 10 and 26 ft acuity was poorer under blue lighting. An increase of 40–50 per cent in angular size of detail was necessary for observers to perform as well as under white lighting. When observers wore -1.0 diopter lenses at the far distance in the blue condition their acuity was statistically indistinguishable from acuity under white light.

The decrease in acuity is ascribed to the axial chromatic aberration of the eye. A blue illuminant typical of selective spectrum lighting systems results in an induced myopia of 0.60 diopters corresponding to a far point of 65 in. Methods of compensating this effect are briefly discussed.

A Comparison Between Human Operator and Optimum Linear Controller RMS-Error Performance—R. W. Roig (p. 18)

The rms-error performance of a human operator in a simple closed-loop control system responding to input signals from a non-Gaussian process was measured and compared with the performance of an "optimum" linear controller. The results show that the human operator produces rms errors which are approximately equal to those produced by a highly constrained optimum linear controller. Comparison of the error-signal waveforms in the human operator system and the linear system reveals some adaptive behavior on the part of the human operator.

Relative Frequency Analysis to Assess Communication Feedback in a Malfunction-Coding Scheme—G. Greenberg, S. A. Greenberg, and E. M. Bennett (p. 22)

Samples of data generated by the coding scheme now being used by the military to collect statistics on equipment malfunctions were

analyzed by psycholinguistic means. Frequency-to-rank distributions plotted on logarithmic coordinates were compared with Zipf's generalization and were found to be markedly aberrant. It is deemed likely that this reflects a lack of sufficient feedback from the users of malfunction data to those who report the data and to those who are responsible for the design of the coding scheme.

Decision Programming: A Model of Man-Machine Control—R. E. Thomas and A. A. B. Pritsker (p. 25)

A stochastic equation is used to generate a sequence of pointer positions on a voltmeter dial. The successive positions are characterized by a "drift" parameter and a "noise" parameter. The voltmeter dial also shows a pair of symmetrical tolerances. A subject and a machine share the task of maintaining the pointer within the tolerances. The task is accomplished by repetitively asking and answering three questions: 1) Is the pointer now within the specified tolerances?, 2) If not, what corrective action is appropriate?, and 3) Was the preceding corrective action effective in maintaining control over the pointer?

Recurrent event theory is used to derive a model for predicting the probability of maintaining the pointer within the tolerances under various "levels of automation." Two cases are reported: control as a function of "full automation" in which the machine makes all three decisions all of the time, and 30 per cent autotion in which the machine makes 30 per cent of the decisions of each decision type in accordance with a random selection in time.

Experiments show that: 1) a process described by the stochastic equation can be maintained within specified tolerances with predictable probabilities when the control is accomplished by repetitive application of the three basic decisions; 2) by providing the controllers with a sufficient number of corrective actions of the proper magnitudes, the mathematical description of the control process as a recurrent event process is appropriate; 3) both the drift parameter and noise parameter are significant parameters, and trade-offs at equal control probabilities can be obtained by suitable combinations of drift and noise.

Contributors (p. 29)
Reviews of Current Literature (p. 31)

Military Electronics

VOL. MIL-6, NO. 1, JANUARY, 1962

PGMIL Past Chairmen (p. 1)
Frontispiece—G. B. Wareham (p. 3)
Direct Energy Conversion—G. B. Wareham (p. 4)

The Present Status of Silicon Solar Cells—P. A. Iles (p. 5)

The present state of the art of silicon solar cells is described. The physical properties, circuit performance, and current lines of research are summarized. Silicon is seen to be competitive in several of the newer approaches to solar cell improvement.

Estimate of Space-Radiation Effects on Satellite Solar-Cell Power Supplies—J. M. Denney, R. G. Downing, S. R. Lackman, and J. W. Oliver (p. 14)

The charged-particle intensity and energy distribution at the heart of the inner and outer Van Allen belts is compared with the experimentally determined radiation sensitivity of silicon solar cells. Energy dependence of the radiation damage and solar-cell characteristics is included in the lifetime estimate of spacecraft solar cells. Use of charged-particle range-energy relations and the differential intensity of the Van Allen radiation results in an estimated effectiveness of thin protective shields. Comparative advantages of thin shields, advanced cell designs, solar efficiency, and solar-cell system over-design are discussed with respect to radiation resistance of spacecraft power supplies.

Characteristics of High-Conversion-Efficiency Gallium-Arsenide Solar Cells—A. R. Gobat, M. F. Lamorte, and G. W. McIver (p. 20)

Gallium-arsenide solar cells having conversion-efficiency values greater than 11 per cent are described. Crystalline properties of gallium arsenide are discussed, and cell design considerations are given. Gallium arsenide provides several advantages over silicon in the fabrication of high-efficiency cells having improved temperature characteristics and higher radiation-resistance properties. Typical cell characteristics are presented and compared with those of silicon cells. In addition, data are given to show the effects on gallium arsenide cells of incident solar energy, temperature, radiation, and life.

Progress in Thermoelectricity—P. H. Egli (p. 27)

Of the several processes by which heat is directly transformed to useful electric power thermoelectricity offers unique advantages for several areas of application. The absence of moving parts and the simplicity promise high reliability, silence, and long-lived, maintenance-free operation both as a power source and as a heat pump for refrigeration and temperature control. A substantial effort devoted to materials development has produced new semiconductors with an integrated theoretical efficiency of about 20 per cent. Further progress in materials development is needed to achieve major goals in both military and commercial applications, but important uses can already be visualized. Small power plants for remote areas and auxiliary power supplies for space vehicles are awaiting engineering improvements, some of which again require improved materials for use as electrical contacts and electrical and thermal insulators. Similarity in refrigeration, important military applications and special commercial devices can be produced with existing thermoelectric materials when engineering problems and the auxiliary materials problems are solved.

Thermoelectric Generator Design, Performance, and Application—T. M. Corry and G. Spira (p. 34)

Many of the practical problems that are encountered in building present-day generators are illustrated. A design procedure for free convection air-cooled generators is described. The performance of power thermocouples as a function of junction temperature is discussed and curves illustrating couple efficiency, power output, heat flux and voltage as a function of hot junction temperature are shown.

The effects of varying thermocouple length on generator efficiency and generator specific power are shown graphically and methods of predicting generator performance are illustrated for thermoelectric materials of equal figures of merit but different values of thermal conductivity. The paper also discusses free convenction heat exchangers and fossil-fuel burners. The thermoelectric generator performance on a watts-per-pound basis is compared with battery- and gasoline-engine-driven generator performance for specific missions.

Thermionic Conversion—State of the Art—T. Jarvis (p. 41)

After a brief discussion of fundamental principles, a family tree of the different types of thermionic converters is presented. The status of individual conversion techniques is then reviewed. A description of the materials problems is given. The paper concludes with projections of development and performance trends of the most important types of thermionic converters.

Fuel Cells—H. W. Fox and R. Roberts (p. 46)

A comparison is drawn between the theoretical efficiencies of heat engines and fuel cells in the conversion of chemical to electrical energy. The electrochemical principles governing the operation of fuel cells are discussed. Short descriptions, including performance curves, are given of a few selected fuel-cell types including low-, intermediate-, and high-temperature cells. and redox and regenerative cells. An example is given of a rough calculation of battery and fuel weight and volume for a given power level and total energy demand.

Radioisotope-Activated Fuel-Cell Electrodes—M. Lang (p. 58)

It has been shown that a catalytic effect can be produced on oxygen fuel-cell electrodes by the incorporation of radioactive isotopes into the electrode structure. Experiments with β emitters have resulted in low temperature and pressure silver electrodes capable of high current drains at favorable polarization values. Analysis of the data indicates support for the hypothesis that radiations exert a significant effect on diffusion control within the pores of the electrode.

Regenerative Hydrogen-Oxygen Fuel Cell—S. E. Voltz and M. D. Read (p. 63)

The regenerative hydrogen-oxygen ion-exchange membrane fuel cell is especially suitable for use in space power systems. During discharge, the anode reaction is $H_2+2OH^- \rightarrow 2H_2O+2e$. The electrons pass out of the fuel cell at the anode to the load, then re-enter at the cathode. The cathode reaction is $\frac{1}{2}O_2+H_2O+2e \rightarrow 2OH^-$. The hydroxyl ions pass through the membrane to the anode; the electrical circuit is thus completed. The cell reaction is $H_2+\frac{1}{2}O_2 \rightarrow H_2O$. During charge, electrical energy is furnished to the fuel cell and water is electrolyzed into hydrogen and oxygen.

Single cells have been cycled continuously for several months without significant decreases in performance. The electrochemical efficiencies

$$\frac{\text{ampere-minutes out}}{\text{ampere-minutes in}}$$

are 95 to 100 per cent and the energy efficiencies

$$\frac{\text{watt-minutes out}}{\text{watt-minutes in}}$$

are as high as 50 per cent. Cells have been operated initially at current densities of 38 and 100 a per square foot at 0.8 and 0.6 v, respectively.

Multicell units have been built and tested. Experimental fuel-cell batteries have been tested under zero-gravity conditions in aircraft and have been flown in missile flights. The results have shown that this fuel cell operates satisfactorily in the environment of outer space.

Hermetically-Sealed Nickel-Cadmium and Silver-Cadmium Storage Batteries—R. C. Shair, G. Rampel, and E. Kantner (p. 67)

The galvanic battery is the most highly developed means of storing electrical energy today. In satellite and space-vehicle applications where auxiliary electrical power is required for extended periods of time, it has been found that the most feasible power supply currently available consists of silicon solar cells used in conjunction with sealed nickel-cadmium storage batteries. They are capable of thousands of repeated cycles and have an energy output of about 12 watt-hours per pound. Sealed silver-cadmium cells are of interest because of their higher output, 24 watt-hours per pound, but they are not as far developed, nor

do they as yet have the cycle life of nickel-cadmium cellls.

In the development of hermetically-sealed nickel-cadmium batteries, the following areas have received considerable attention: 1) Hermetic seal, 2) Continuous overcharge capability and low internal cell pressure, 3) Separator, and 4) Cycle life.

In the development of hermetically-sealed silver-cadmium cells, four technical problems have received considerable attention: 1) Separator, 2) Improved silver electrode capable of delivering energy at the Ag^{+II} potential, 3) Continuous overcharge capability, and 4) Cycle life.

Although other direct-energy conversion systems appear to be promising and are being intensively developed, it is expected that the nickel-cadmium and silver-cadmium storage batteries will continue to be of importance for many years to come.

New Materials for Primary Batteries—G. S. Lozier (p. 72)

The selection of new anode-cathode combinations for primary cells is described on the basis of ampere-hour capacity, theoretical and operating potential, handling properties with respect to the design of primary batteries, and limitations placed on the selection of active components by unsusual electrolyte requirements. Theoretically, for the design of dry and reserve primary cells, the most desirable anode materials are magnesium and aluminum; the most desirable cathode materials are the nitro-organic compounds, N-halogen organic compounds, silver (II) oxide, copper (II) oxide, nickel oxide, and mercuric oxide. Such other possible anode materials as titanium, alkali metals, and hydrocarbons, and cathode materials such as oxygen, sulfur, halogens, oxides, and chlorides, are also considered.

A magnesium/magnesium perchlorate/m-dinitrobenzene dry cell with an experimental capacity of 90 wh/lb and estimated maximum available capacity of 150 wh/lb is described. The basic relationships between the cathode potential of aromatic nitro compounds and the nature of substitution groups are illustrated. The development of high-capacity dry cells with a perchlorate electrolyte, a magnesium anode, and a cupric oxide or synthetic manganese dioxide cathode is described. The capacity of a magnesium/magnesium perchlorate/mercuric oxide cell on a 30-minute discharge rate with a voltage tolerance of ± 5 per cent is 50 wh/lb and 3.0 wh/cubic in.

The Magnetohydrodynamic Power Generator—Basic Principles, State of the Art, and Areas of Application—A. R. Kantrowitz, T. R. Brogan, R. J. Rosa, and J. F. Louis (p. 78)

The paper opens with a review and discussion of the basic principles of MHD power generation. It is seen that the MHD generator operates in a manner similar to that of a conventional generator in that the "armature" of the MHD is a hot, high-speed electrically-conducting gas, while the force or torque-required to move a metallic conductor through a field is replaced by a pressure gradient in the gaseous armature. Thus the functions of turbine and generator are combined in a single machine. Because this machine has no moving parts, it can, in principle, accept a working fluid at very high temperature.

After a derivation of the basic MHD-generator flow equations a brief synopsis of losses in an MHD generator is given. The nature of these losses is such that the MHD generator is applicable where large amounts of power are involved. In bases, the Hall effect can be very pronounced, and its influence on MHD generator design and performance is pointed out.

There follows a brief statement of the state of the art in MHD-generator development at the Avco-Everett Research Laboratory. It is shown that gases produced by conventional heat sources can be made adequate conductors of electricity for use in an MHD if a small amount of easily ionizable impurity called seed is added to the gas. Recent developments in superconducting materials, plus detailed studies of MHD-generator fluid mechanics in a large combusion-driven generator point to early realization of the potential of MHD.

Finally, some potential applications of MHD are suggested. These applications lie in the areas of central station power generation, shipboard propulsion, limited duration, high-power units, and energy storage and discharge in some ranges now covered by capacitor and inductive devices.

Solar-Cell Power Systems for Space Vehicles—N. W. Snyder (p. 84)

For operational purposes, solar-cell power systems are being used in the 30 or 40 different spacecraft now planned for flight. The range of power is from 15 to 500 watts. Both nonorientation and orientation of paddles to the sun are being used. An approximate break-even point between excessive weight of solar cells for non-oriented systems and weight of the orientation servomechanism system for solar-oriented systems occurs for a power level of 100 watts. Nickel-cadmium batteries have been used for the storage of electrical energy, whether for providing power during shadow periods encountered by low-altitude spacecraft or providing peak power during telementry for interplanetary flights. The specific weight of such power systems varies from 750 or 1000 lb/kw to 500 lb/kw for orbits from 300 miles (statute) to 22,000 miles (synchronous orbit). Reduction in weight of batteries as well as solar cells needed for battery charging as altitude increases is responsible for this decrease in specific weight because of the decreasing time of shadow encountered by an orbiting spacecraft.

Solar Direct-Conversion Power Systems—W. C. Cooley (p. 91)

A survey is made of the present status of technology of solar photovoltaic, photoemissive, thermoelectric and thermionic power systems for spacecraft. The subjects of radiation damage to solar cells, power-system design, and solar simulation are reviewed. Various types of solar power systems are discussed and compared with respect to weight, availability, environmental tolerance, and cost. It is concluded that solar photovoltaic and solar thermionic systems are most desirable for power levels up to 3 kw. However, the life capability of thermionic converters has not yet been established. Solar thermoelectric and photomissive systems will be less desirable because of their lower efficiency and, therefore, larger area per unit power output, except for missions where radiation resistance or economy are paramount considerations.

The Cesium-137 Thermoelectric Generator—H. O. Banks, Jr. and W. W. T. Crane (p. 98)

Designed for the initial application of supplying power for an under-sea seismic station to be supervised by Lamont Geological Observatory researchers, this cesium generator incorporates an external shell that will withstand compressive forces at the greatest of ocean depths and a power-conversion system employing lead telluride thermocouples mounted on a printed circuit board. A combination radiation shield and heat sink, surrounded by a special complex of thermal reflectors and compacted insulation, utilizes practically all the decay heat.

A very high degree of safety from radioactivity is assured, due to double encapsulation of fuel increments, an ultrastrong radiation shield for containment of the latter, and an external shell that will withstand 16,000 psi pressure.

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Snap Radioisotopic Power Systems—J. G. Morse (p. 34)

Aerospace Nuclear Power Radiation Safety—Dr. J. A. Lieberman, Lt. Col. J. A. Connor, Jr., and Lt. Col. J. E. Bicknell (p. 45)

We see nothing that would prevent our use of aerospace nuclear devices. On the other hand, we realize that much analytic, experimental and real test work must be accomplished to satisfy ourselves that the risks have been eliminated or appropriately minimized. Thus, we can see that the direction in which we are walking on this thermal tightrope is toward an increased operational flexibility.

The availability of nuclear power will be one of the principal factors that will give man the capability to explore the great distances of space. The radiation risks associated with development and use of nuclear space systems are expected to be much less than the risks encountered in the development of such technological advances as electric power, the airplane or chemical rockets. The added operational costs to achieve protection from these risks, though admittedly high, can be kept within reason. These costs, however, will be small as compared to the operational gains derived from employing nuclear power—for in many instances, the job just cannot be accomplished without the use of atomic energy.

The Developing Role of Nuclear Energy in Aerospace Technology—T. von Karman (p. 49)

Some Restrictions on Nuclear Ramjet Engine Performance Imposed by Control System Component Limitations—M. M. Weintraub (p. 52)

There is presented a brief technical discussion of ramjet propulsion thermodynamics. The more important controllable variables affecting thrusts are described.

Two important performance parameters used in the evaluation of jet engines are explained, thrust coefficient and specific impulse. These parameters are compared for chemically fueled and nuclear powered ramjets, rockets, and turbojets.

Theoretically maximum performance, in terms of altitude and Mach number, are computed for an ideally low-drag ramjet vehicle incorporating a nuclear power plant.

Considering present state of the art controls and materials limitations, some restrictions to the ideal performance envelope are shown.

Current Status of the Nuclear-Powered Arc Jet Rocket Engine—R. R. John, J. Connors, A. Mironer, and M. Yarmovych (p. 60)

The present paper is in the nature of a status report on the performance and possible application to space missions of the thermal arc jet rocket engine. The following areas are discussed:

1. Arc Jet Operation and Performance
2. Preliminary Arc Jet System Considerations
3. Orbit Transfer of a 24-Hour Communications Satellite

The paper includes discussions of electrode

configuration, liquid versus radiation-cooled engines, and arc engine starting, and contains speculations on a battery-powered flight test, cryogenic versus noncryogenic propellants, and alternating versus direct-current arc jet operation.

Nuclear Rocket Engine Dynamic Study—P. J. Blake and W. H. Esselman (p. 78)

Start-up studies are reported considering first just the temperature coefficient of reactivity associated with the fuel temperature, and second, just the density coefficient of reactivity associated with the hydrogen density in a control region.

Preliminary results are given of a nonsimultaneous digital-analog study of start-up which utilizes a detailed digital code description of heat transfer and fluid dynamics, and an analog description of reactor kinetics and controls.

Thrust maneuvering capabilities are explored and used as a basis for comparing control designs. Both fast and slow controllers capable of mainintaining propellant exit temperature with $\pm 50°R$ are discussed.

Nuclear Auxiliary Power Unit for Lunar Exploration—A. J. Streb, R. J. Wilson, and T. S. Bustard (p. 85)

Unmanned soft lunar landing experiments by the United States are currently being planned by the National Aeronautics and Space Administration. All of these experiments will require some form of electrical power; and their success or failure will depend upon the development of a suitable, reliable electrical power generation system. The system utilized must be compact, lightweight and rugged.

Certain requirements for such an experiment could be met by solar cell arrays. The reliability of solar cells has been well established; however, their usefulness for this mission is inherently limited. Experiments conducted during the lunar night require a large storage capacity, if solar energy is to be the spacecraft's only source of power.

A radioisotope-fueled thermoelectric generator can fulfill all spacecraft power requirements continuously throughout the lunar day or night without special orientation. A radioisotope, such as Curium-242, may be used as the thermal energy source for a lunar experiment of short duration (90 to 120 days). Curium-242 does not occur in nature, but may be created by the neutron irradiation of Americium-241. This radioisotope requires very little radiation shielding to protect sensitive equipment, because of the low gamma flux associated with its decay.

The rigors of the lunar "climate" produce an environment which present-day electronic equipment will not tolerate. By utilizing waste heat from the radioisotope generator, the electronics compartment temperature may be controlled within acceptable limits. All subsystems within the generator may be duplicated to improve its reliability. This duplication, combined with the inherent dependability of static conversion, results in a system with a very high overall reliability. Such a system can be developed for a soft lunar landing experiment within current state-of-the-art capabilities.

A p-i-r Semiconductor Radiation Detector for use with Beta and Gamma Rays and Minimum Ionizing Particles—N. A. Baily, J. W. Mayer, and R. J. Grainger (p. 91)

Experimental Results of Rapid In-Core Flux Mapping Techniques in the Plum Brook Reactor—R. Steinberg (p. 97)

The problems associated with flux mapping in the Plum Brook Research Reactor, which employs an 18 plate Materials Testing Reactor type fuel element, are discussed fully. Design of a flux survey instrument is presented which, utilizing four solid state fission probes, makes it possible to map the complete Plum Brook core in a little over 6 hours, with the data presented in a form immediately available for analysis. Mapping a fuel element (from even 30 ft. above the core) does not require an accurate above water positioning system, yet a high degree of accuracy (± 0.1 in.) in referencing in-core measurements has been obtained.

The effect of radiation on the semiconductor detectors and the operating characteristics of the instrument, along with typical flux profiles obtained in mapping the Plum Brook Reactor are presented.

Transient, High Flux Instrumentation Experience at KEWB—E. L. Gardner, R. N. Cordy (p. 105)

KIWI Ground Test Neutronics Instrumentation—J. McLeod (p. 113)

A Servo-Stabilized Analogue-To-Digital Converter for High Resolution Pulse-Height Analysis—R. L. Chase (p. 119)

A 4096 channel pulse-height analyzer has been constructed to exploit the high resolution attainable with semiconductor junction charged particle detectors in the 0 to 40 Mev range. The use of so large a number of channels can only be justified if the drift in the system can be held to less than one channel. It was felt that, using conventional techniques, it would be very difficult to stablize the linear amplifier gain, the converter gain and the converter zero to a part in 4000. A servo-stabilized system was therefore adopted which assures long term system stability without imposing unreasonable restrictions on component stability.

A stable pulse generator produces two reference pulses, one 8 times as large as the other, and presents them alternately to the preamplifier input along with the detector pulses. Reference and detector pulses are amplified and measured by the same analogue-to-digital converter. The small reference pulses should fall in channel 512 and the large pulses in channel 4096. The amounts by which the reference pulses miss their intended channels constitute the error inputs to two integrating digital servos. The large-pulse servo controls the converter clock frequency and the small-pulse servo controls the converter zero setting. The servos have sufficient lock-in range to compensate perfectly for gain change of $\pm 3\%$ and zero changes of $\pm 1.5\%$. Because they are digital in nature they do not drift nor lose control even if an appreciable number of the reference pulses cannot be measured because the converter is busy with detector pulses.

High Temperature Fission Chambers—J. Duchene (p. 123)

French Direct Conversion Research—M. Surdin (p. 128)

Control Systems for the KIWI-A Nuclear Reactors—G. K. Hess, Jr., H. B. Demuth, E. A. Brown, and R. R. Mohler (p. 134)

This paper presents an overall picture of the Kiwi-A reactor control systems. The techniques of analysis and design of the control systems, the reactor power and propellant flow rate control hardware, the control system performance during tests, and special measurements made on the control systems to check analytical predictions are discussed. Problems presented by future reactors and some new control systems for these reactors are described.

Logarithimic Power Control in KIWI-A Reactors—E. A. Brown (p. 145)

Power control systems for rocket propulsion reactors are unusual in that power must be increased several orders of magntidue in less than a minute. This paper describes the logarithmic power system developed at Los Alamos and used during the operation of Kiwi-A′ and Kiwi-A3. Transfer functions are given for the system. Analog computer and experimentally measured data are presented showing the system response to step changes of logarithmic power demand, representative start-up programs, reactivity disturbances, and a rod-generated power excursion followed by a scram. The logarithmic power system had a band-width of one cps and a dynamic range of approximately six decades.

SNAP II Rotational Speed Control—W. E. Dauterman and E. J. Viton (p. 151)

The design and development of the rotational speed control for SNAP II has progressed to the point where experimental results have confirmed the present breadboard design approach. Frequency is controlled within $\pm 1\%$ and all functional control specifications of the SNAP II system have been met.

High temperature component testing has shown that basic components are available for operation at elevated temperatures (350°C) in most areas. High temperature diodes are still not available.

KIWI-BIA Test Facilities and Procedures—J. Henshall and S. Singer (p. 158)

Characteristic Control Requirements for Nuclear Rocket Engines and Vehicles—C. T. Donnenworth (p. 162)

Because efficient staging of rocket vehicles, in general, requires a rapid thrust buildup, a rapid startup will be essential in nuclear rocket engines. However, the startup and staging methods selected must not compromise system reliability or safety. It should also be realized that the minimum startup time depends for the most part on the maximum allowable fuel element temperature rise rates. In addition, the relatively long interstage section and the thrust buildup characteristics presents unique, if not complex, problems for the analysis of the staging sequence.

The two thrust vector control systems presented here, although reflecting some degradation in overall performance, do not exhibit enough advantage of one over the other to select the optimum system for the early phase of a nuclear vehicle program. Further evaluation, for proper selection, is highly dependent on the engine development approach and study of the engine environments and operational requirements.

The instantaneous and sharp cutoff of thrust, experienced in the chemical engine, is not feasible in the nuclear rocket engine since the fission product heat must be removed to prevent material temperatures from subsequently reaching unacceptable levels of engine integrity is to be maintained with all components in operating condition. The tail-off performance produced by after-cooling must be factored into the determination of the final burnout velocity, but it must certainly be predictable and repeatable, in both magnitude and time, in order to establish acceptable vehicle performance, stability, and control.

Radiation—Tolerant Logarithmic Amplifier—R. R. Hoge (p. 167)

In any conceptual design of a flight vehicle utilizing nuclear-type propulsion the amount of necessary shielding will detract from the allowable payload. The ability of electronic instruments to tolerate radiation and temperature extremes will then be of prime importance in these designs. This report describes the development and performance of a radiation and vibration tolerant instrument for use in the neutron flux control of a nuclear ramjet engine.

Radiation Levels Governing Nuclear Rocket Ground Instrumentation—W. E. Ivie, Jr. (p. 174)

A rocket vehicle with a nuclear propulsion system assumes the environment of the reactor: specifically, the high intensity neutron and gamma radiation fields. The rocket system considered here is a booster-type vehicle of ap-

proximately 1.25 million pounds.

Reactor power requirements for the specified mission and the necessity of minimum schielding results in a neutron flux in excess of 6×10^{13} n/cm²-sec ten meters from the reactor core, and a gamma flux of approximately 10^{15} γ/cm²-sec at the same distance.

The environment at the lauch site is affected by intense gamma radiation from the reactor during reactor run-up, hold-down for systems check, and also for a short time after lift-off. In addition, there will be fission product release resulting in ground contamination, and gamma radiation in the air both vicinal to and remote from the launch site.

Assuming that the reactor and booster vehicle are to be recovered, activation radiation induced in the structure, and fission product release from the shutdown reactor must be evaluated.

The requirements for instrumentation around a nuclear rocket launch site are, indeed, many and diverse. The demands upon a monitoring and measurement system are constant at all times, and during nuclear operations are severe. Although the magnitudes of nuclear radiations shown here are prodigious, the problems presented by them are not insurmountable.

This paper analyzes the various radiation environments, and outlines on-site and off-site radiation instrumentation requirements.

Electropneumatic Control Systems for Aerospace Nuclear Propulsion Applications—C. B. Sung and J. R. Farron (p. 182)

This paper describes recent advances in electropneumatic control systems for aerospace nuclear propulsion. The capabilities, limitations, and recognized problem areas are defined and reviewed, and reasons for the selection of this type of control systems are discussed.

The potential of electropneumatic control systems for broader aerospace applications is discussed, where less emphasis may be placed on environmental restrictions but more emphasis on minimum weight, greatest hardware simplicity, integration and self-containment of the control system and power package, and long-term storage capability. The paper is concluded by outlining the further development effort required to realize the described potential.

Development of a High Temperature and Radiation Resistant Linear Motion Servo Actuator System for Nuclear Reactor Control Rod Application—J. S. Sulich and M. H. Cardon (p. 193)

This paper discusses major problem areas encountered in the design, construction, and development of a servo actuator system for positioning the control rods of a nuclear ramjet engine test reactor. The actuator discussed is 40 inch linear stroke electropneumatic servo actuator capable of operating throughout the temperature range of 70°F to 1200°F part temperatures ranging from 70°F to 1060°F. The discussion covers major components as well as the complete actuator assembly. Important details of the mechanical design and selection of materials are presented together with a summary of the measured performance levels. The component and system test programs are described. Life data based on testing under the specified, room and high temperature environment conditions, is presented.

Performance Characteristics of a High-Temperature Servomechanism for Reactor Control Rods—R. B. Hollstein, M. J. Nutter, and C. D. Stout (p. 204)

Feasiblity of servo operation, with supply gas and average part temperatures over 1000°F, for periods over two hours is well established. Performance required for vernier rod control in the Tory II-C reactor was nearly achieved with the first prototype design. Analytical study revealed characteristics of the pneumatic valve and motor significant in designing performance into systems of this type, and modifications to a room-temperature motor predict improved resolution and dynamic stiffness for the second design. Analog model studies show the effects of supply-to-ambient pressure-ratio variation on valve-motor characteristics are tolerable for Tory II-C reactor controls.

Observations on the Kinetics and Control of Gas Core Reactors—R. D. MacLain and J. W. McKee (p. 212)

An expression is developed relating fission product residence time to fission product mass number for a hypothetical gas core vortex reactor. Utilizing the expression and considering that the fission products, Kr-87, Br-87, Kr-93, I-137, and I-138, are also delayed neutron precursors, a modified effective delayed neutron fraction is calculated for U-233, U-235, and Pu-239 fueled cores. Temperature coefficients for the reference cores are developed as functions of reflector temperature, assuming a Maxwellian neutron spectrum. Utilizing these power coefficients and the modified effective deleayed neutron fractions, the consequences of reactivity perturbations in the reference cores are analyzed. It is shown that optimally moderated gaseous fission cores should possess a high degree of inherent stability.

An Instrumentation System for a Nuclear Rocket Engine Reactor—J. H. Jurmain (p. 222)

A unique data acquisition system has been developed to cope with the problems of testing Kiwi Reactors in the Rover Program. This uniqueness is due to the large number of parameters measured, the extremely high reliability and accuracy requirements, extreme requirements for system flexibility, and the wide ranges of parameters.

The requirement for up to 1,500 simultaneous measurements with one-percent system accuracy requires automation of checkout, monitoring, and calibration, and demands special design, modification, and maintenance of otherwise routine components. Calibrations are required to hold for many hours on all components.

Data are transmitted via a two-mile hardwire system.

Considerations in the Design of a Goto Logical System—W. Mead and A. Wolterman (p. 228)

Recently, the Goto twin circuit often has been discussed in the literature. The basic circuit operation and alyalyses of the circuit have been presented in the References in a number of forms. The purposes of this paper are to briefly review the Goto circuit operation, to present a new method of graphical analysis, to illustrate the utility of the graphical analysis in the design of Goto circuits which are to exist in a high radiation environment, to discuss the requirements on a radiation resistant Goto circuit clock generator, and to present experimental data on the resultant logical system which has been designed to operate properly at an integrated neutron flux level of 10^{16} nvt.

Reliability Limitations on Electronics for Nuclear Propulsion and Space Power Systems—F. Larin (p. 238)

Although a large amount of data is available on the temperature and radiation effects on electronic components, it does not contain the necessary engineering information that can be found for the more conventional space electronics design. For nuclear applications, the electronics designer needs information on a much greater number of components because of the wide range of temperature and radiation environments.

A coordinated development and reliability program should be started now to assure the usefulness of nuclear propulsion and space power by providing the necessary reliable components and the engineering design information reqiured to design the electronic equipment.

An Instrumentation System for Temperature Profiling of Large Liquid Hydrogen Dewars—A. Engel (p. 243)

Liquid Hydrogen is used as a propellant for Project Rover nuclear-powered rocket engines. An instrumentation system is described which measures, records and displays vertical temperature profiles in two 50,000 gallon liquid hydrogen dewars. Platinum-resistance thermometers in each dewar are sampled sequentially. Measurements are digitized, printed, transmitted by PCM for remote recording, and reconverted to analog form for real-time graphical display. Measuring ranges are 30 to 460 degrees Rankine (°R), with 1% absolute accuracy, and 30 to 53°R, with 0.5% absolute accuracy.

High Temperature Thermocouples in the Rover Program—A. R. Driesner, C. P. Kempter, C. E. Landahl, C. A. Linder, and T. E. Springer (p. 247)

Tungsten/tungsten-rhenium thermocouples have been successfully used for various hydrogen gas temperature measurements in the Kiwi-A reactors of the Rover nuclear propulsion program. The most useful combination for these thermocouples has been tungsten coupled with a tungsten-25 weight per cent rhenium alloy. This alloy exhibits a solidus temperature slightly over 3100°C, has considerably more room temperature ductility than tungsten, and yields an electromotive force of about 40 milli-volts against tungsten at 2300°C. In one design 60 mil W and W-Re wires are pressed and swaged into a tungsten block. The wires are passed through an insulated pressure seal. The time response of the thermocouple is in the one second range. These thermocouples may be used in an automatic exit gas temperature control system in some subsequent Rover tests.

A Note on Platinum/Platinum-Rhodium Thermocouple Uncertainty—W. E. Bostwick (p. 253)

The term uncertainty is used rather than instability. Stability implies that a device can be calibrated to a known and repeatable small error. As will be shown for the temperatures considered, this definition of stability may not be true.

Two configurations of platinum/platinum-10% rhodium thermocouples were developed for the Tory II reactors. The manufacturer checked outputs at 2400°F. Subsequently, we ran tests between 2000 and 2400°F to determine how dependable the initially measured outputs were. The uncertainty turned out to be about ±10°F, over the rather narrow test band.

As a result of these first uncertainty tests, we decided to see what effect, if any, different types of junctions have on the uncertainty. This report has to do primarily when results of tests on crimped, twisted, hydrogen-arc-welded, and resistance-welded junctions. A horizontal tube furnace was used from 1500 to 2300°F and a vertical tube furance from 2300 to 2800°F. Some unexplained things happened when the transfer to the vertical tube furnace was made.

Reference grade, 10-ml thermocouple wire with alumina tube insulation was used for most tests.

In general, the uncertainty shows up as an error band of fairly constant width. This means that it cannot be expressed as a per cent of indicated temperature. The band width tends to become narrower with increasing temperature up to 2300°F or so; 20°F is still a "good" figure for it at 2300°F. Hydrogen-arc

welding should be avoided. The importance of an annealing cycle to test temperature is shown by the curves.

Wire size definitely affects the uncertainty picture. Even 20-mil platinum/platinum-rhodium wire has an appreciable uncertainty. Hence, we have begun a series of tests using platinum resistance thermometers. These tests on 3.5-, 10-, 20-, and 30-mil wire should show at least a trend. Results to date are reported herein.

Radiation Effects to Flight Control Systems—First Lt. V. G. Smalley and P. Polishuk (p. 260)

This paper presents some of the results of programs being carried on at the Flight Control Laboratory, Aeronautical Systems Division, W-PAFB, O., in the development of techniques to design and evaluate high temperature radiation resistant Flight Control Systems. Sources of radiation environment being investigated are nuclear powered vehicles, nuclear bomb detonations, and space radiation. To date, tests performed in actual reactor environments indicate the feasbility of designing Flight Control Systems for certain nuclear applications. The results of programs to develop high temperature radiation resistant Flight Control components and systems such as synchros, pressure transducers, accelerometers, temperature amplifiers, tachometers, electronics, inertial components, and control systems indicate further work is necessary to meet all environmental criteria encountered in nuclear applications.

Reactor Irradiation of Semiconductor Devices—L. Taylor (p. 280)

This experiment surveyed some parameter changes of several types of semiconductor devices exposed to a reactor radiation environment. Twelve irradiated and eight control specimens from production stock of two diode and eleven transistor types constituted the experimental groups. The experimental region of the reactor was initially flux mapped, and a flux determination was made for each irradiation. The total dose was about 10^{14} fast neutrons/cm^2 and 10^8 ergs/gm(c) of gamma rays.

Measurement of electrical parameters before, during, and after irradiation indicated a tolerance limit for some devices. The most radiation-resistant transistors measured were silicon double-diffused mesa units types 2N702 and 2N726, and germanium diffused-base mesa units types 2N710 and 2N797. Voltage regulator and switching diodes were hardly affected. Radiation tolerance was greater in the devices with a narrow base region.

The increase in tolerable dose with increasing gain-band-width product is less for germanium than for silicon. There appears to be only a small difference between silicon and germanium in allowable dose for very-high-frequency devices.

The Effects of Nuclear Radiation on High Temperature Thermistors—W. R. Owens (p. 296)

High temperature thermistors, 100°C to 600°C, were tested before, during, and after irradiation in the Ground Test Reactor at The Nuclear Aerospace Research Facility, General Dynamics/Fort Worth. The radiation environment was held constant at 2.2×10^{10} n_f/cm^2-sec (n_f=fast neutrons with energy>2.9 Mev) and 4.2×10^8 ergs/gm(C) hr γ for a period of 91 hours. Resistance as a function of temperature was measured for high, medium, and low resistance type thermistors. No permanent damage was observed, but transient effects were severe at high resistance values.

The transient effects were due to ionization of the air and the thermistor material by the nuclear environment. The ionic conduction in the thermistor material was highly temperature dependent.

Radiation Effects Considerations on Materials in Cryogenic Systems of Nuclear Rockets—J. W. Gordon (p. 299)

One technique of using nuclear energy for propulsion of a rocket system involves the use of a fission reactor as a heat source for a combination coolant-propellant. One of the factors that will influence the performance of this type of vehicle will be the radiation resistance of the materials, parts, and components that are used in its design. Another important factor is the effect of nuclear radiation on materials at cryogenic temperatures.

This paper presents a discussion on the effects of nuclear radiation on materials exposed to a cryogenic environment. Sealing materials, lubricants, thermal insulation, and structural materials are discussed with respect to radiation stability. Some experimental data on the effects of simultaneous exposure of metals to nuclear radiation and cryogenic temperatures are also presented.

Annealing of Reactor Radiation Damage in Lead and Bismuth Tellurides—J. C. Corelli, R. T. Frost, and D. M. Amorosi (p. 303)

Nuclear-Radiation-Resistant Circuitry Design and Test—J. R. Perkins (p. 310)

Recent technological advances in the utilization of nuclear energy as a weapon and nuclear reactors as propulsion systems and in other applications have resulted in imposing severe radiation environments on automatic control systems. The work described in this paper concerns the design and testing of electronic circuits which comprise these systems. By special design the nuclear radiation damage thresholds of these circuits were raised from 10^{14} to 10^{17} fast neutrons/cm^2. The nuclear environment in which the circuits were tested was generated by a 3-megawatt ground test reactor, the integrated dose over a 100-hour period being approximately 5×10^{16} fast neutrons/cm^2. Twenty of the twenty-four circuits tested were operating properly at the termination of the test.

Nuclear Environmental Effects on Space Guidance and Control Systems—W. L. Fink (p. 316)

The guidance and control system that is considered for analysis is a programmed inertial guidance unit with an astro-tracker for space coordinate corrections. For most missions the effects of space radiations on systems will be trivial; however, Van Allen radiation and solar flares can increase the dark current on the astro-tracker sensing element. Reactor radiation from the main propulsion system will cause degradation of: electrical wiring in servo valves, semiconductor electronics in the computer system, seals in the hot gas actuators, and solid or liquid propellent gas generators. Combinations of judicious material selection, design modifications, relocation of systems, and shielding will alleviate problems associated with the guidance and control systems operating in a nuclear environment.

Atmospheric Diffusion From a Point Source—R. Le Quinio (p. 320)

The Design and Test Results of Some High Gain Radiation Resistant Magnetic Amplifiers, Magnetic Voltage References, and Components—J. Montner (p. 326)

A number of computing and control type magnetic amplifiers, operating from 4800 and 400 cps power sources, were designed to withstand radiation levels in excess of 10^{15} nvt (fast neutron). They were functionally tested and continuously monitored during such a radiation exposure. The circuits incorporated features to compensate for a factor increase of 500 in diode reverse current. Half of the amplifiers used a conventional IN538 diffused silicon junction diodes and the other half used special radiation resistant, thin based, silicon junction diodes.

The results show that the combination of radiation resistant rectifiers together with the experimental design techniques can provide reliable radiation resistant computing and control circuitry for fast neutron levels approaching 10^{16} nvt.

Development of Instrumentation for use in Nuclear Environments—P. N. Mace (p. 339)

The nuclear environment to be encountered in testing and operating nuclear rocket engines makes the development of reliable instrumentation imperative. A limited program of testing various types of transducers has been undertaken at LASL. A description of the methods and facilities used is followed by detailed descriptions of tests carried out at LASL on various types of pressure-actuated devices. Techniques which may prove effective in improving instrument reliability are mentioned, and plans for further research and development in this area are discussed. In conclusion, the nature and scope of the problem are again referred to, with emphasis being made on the need for a better definition of the problem and a greater effort toward its solution.

The Effects of Steady State and Pulsed Nuclear Radiation on GaAs Tunnel Diodes—W. A. Bohan and A. J. Wager (p. 346)

Successful entrance into the age of nuclear propelled vehicles demands not only solution of the myriad problems of reactor design and vehicle structures but also electronic equipment capable of operating during prolonged exposures to nuclear fluxes. If these vehicles are to be employed for military missions, the electronic equipment must be capable of also withstanding the intense pulses of nuclear radiation which result from detonation.

The IBM Space Guidance Center is engaged in studies leading to the design of missile guidance equipment which will operate in these environments. This paper describes studies which have been made on the utility of gallium arsenide (GaAs) tunnel diodes for equipment which must operate in both the reactor and nuclear weapon environment. The results of experiments to determine the effects of radiation produced by steady state and pulsed nuclear reactors on experimental tunnel diodes are described and compared with the theory governing tunnel diode behavior.

Optimization of Interplanetary Propulsion Systems—Prof. J. Martelly (p. 355)

The classical optimization calculations are extended in case of an electric multistage propulsion system. That which consists in utilizing an energy generator composed of many elements, some of which are jettisoned during the trip. It is shown that the performances are thus increased when the payload is less than $\frac{1}{4}$ of the initial total mass. Also reliability is increased. A simplification of the optimization calculations, as well as the discussion of it, is obtained by using non-dimensional variables; thus the number of independent parameter is decreased from 3 to 1.

Airborne Range Stations for Control of Nuclear Missile Test Vehicles—Dr. W. J. Hesse and L. J. Boyer (p. 363)

A cardinal principle of nuclear ramjet powered missile flight tests is full-time, radar tracking and radio-command control of the missile's flight path supplemented by multiple fail-safe flight termination systems to maintain the missile within a localized test area where nuclear radiation will not endanger the civilian population. The number of range stations to fulfill this service would become excessive if surface stations were used due to radio-line-of-sight limitations. Airborne range stations represent the best solution; and, under certain conditions of very low altitude flight, the only practical approach to full-time tracking and control. A turbojet airplane of the Boeing C-135 type suitably equipped with radar, telemetry

receivers, radio-command control and communications equipment can function as an independent command control center or as a relay station between the missile and a surface control center. This flexibility of operation enhances the reliability of the overall range system. Existing range technology is adequate; however, integration of functions with a high degree of reliability onboard a single airplane is necessary.

Dynamic Heat Transfer Characteristics of a Nuclear Rocket Reactor—F. D. Retallick and B. L. Pierce (p. 369)

The nuclear rocket engine is required to start or change power levels in very short times. This requires that limitations on fast transients be well known and the transient flow and power schedules designed to avoid these limitations. At the same time it is desired that the schedules allow the least use of propellant at other than the maximum specific impulse. Limitations on reactor transients as a result of heat transfer phenomenon consist of thermal stresses, flow choking in the reflector or core cooling passages, laminar flow instability, and two phase flow into the core resulting in unpredictable reactor power perturbations. Studies have been made showing the effect of power and flow schedules on the maximum fuel temperature and the propellant exit temperature. The model used for calculation consists of a single flow channel and its accompanying material for both the reflector and the core.

Computations performed for increase and decrease in thrust show the effect of the power schedule leading or lagging the flow schedule. It is found that the power schedule should lead the flow schedule on an increase of thrust and lead it on a decrease of thrust if it is desired to hold a constant propellant exit temperature.

If for some reason propellant flow to the reactor is instantaneously lost and the reactor is scrammed, it is shown that flow must be resumed in adequate amounts for cooling within 1 second or damage to the core will result.

Realistic Evaluation of Shadow Shields for Space Nuclear Systems—S. T. Friedman (p. 378)

The Outside Test Tank is the only nuclear shielding test facility in the United States suitable for investigating the nuclear characteristics of shadow shield geometries such as will be required to protect components and man near nuclear systems operating in outer space. The OTT is designed so that only the radiation of interest, that is, neutrons and gamma rays penetrating or originating in the shadow shield materials, is measured.. No radiation is measured that is scattered by air or ground. The only radiation that reaches the detectors penetrates shield components on the direct line of sight between the test reactor, the shield, and the test radiation detectors.

The design and operation of the Outside Test Tank are described. Problems encountered during testing are discussed, as are the instruments and devices used to measure neutron and gamma ray dose rates and fluxes. A number of unusual phenomena that were discovered are examined. Tested configurations included such high temperature shielding materials as W and LiH.

In summary, the information presented in this paper proves that realistic evaluation of actual nuclear shadow shield configurations can be made conveniently and relatively inexpensively without having to test in the vacuum of outer space. The data measured in the Outside Test Tank clearly demonstrate that the design of efficient shadow shields for space nuclear systems is not nearly as straightforward as has been suggested.

Announcement of Future Meetings (p. 385)
Errata (p. 386)

Product Engineering and Production

Vol. PEP-6, No. 1, March, 1962

Design for Product Improvement—H. E. Paschon (p. 1)

The development engineer has to deal with nature in an imperfect state where theory is frequently hidden from sight by the complexity of the interactions involved. The problems he has to deal with are, in general, too complex for exact analysis. He must learn to achieve the proper balance between daring and caution, idealism and realism, theory and practice. In his thinking he must be practical in character, evaluating the risks and calculating the probabilities in each situation.

Value Engineering—A. D. Zappacosta (p. 4)

This paper defines value engineering, shows why it is necessary, and emphasizes the engineer's responsibility for using engineering disciplines in the design of a product. Recognizing that value engineering is a duty of the professional engineer, the paper stresses application of value engineering to attain Armed Services goals, and reduce costs while speeding up delivery of the weapon system.

Many engineers, designing complex military equipment, become so engrossed with the input and output performance of a "black box" that they overlook the need for understanding the operational end-use of the equipment. This human tendency results at times in the engineer over-designing the equipment and, in some cases, creating inadequate designs. The required engineering disciplines to increase product-design effectiveness are described. Trade-off decisions which influence the total cost of a weapon system are suggested, and a general method given for quantitatively documenting the cost.

Thermal Considerations for Plastic Encapsulation or Coating in Electronic Product Design—D. R. Fairbanks and M. Mark (p. 11)

Heat Transfer in Coaxial Lines in Still Air—Z. M. Slusarek (p. 13)

The satisfactory performance of microwave transmission lines, operating under high power, largely depends on their capacity of maintaining the operating temperature below the specified limit. The method presented here will enable the mechanical as well as electrical engineer to determine speedily the temperature in the inner and outer conductors of coaxial line operating under any power, size and ambient conditions.

Radio Frequency Interference

Vol. RFI-4, No. 1, February, 1962

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Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and *Electronic Technology*, Dorset House, Stamford St., London S.E. 1, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

The Index to the Abstracts and References published in the PROC. IRE from February, 1961 through January, 1962 is published by the PROC. IRE, June, 1962, Part II. It is also published by *Electronic Technology* and appears in the March, 1962, issue of that Journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

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The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

UDC NUMBERS

Certain changes and extensions in UDC numbers, as published in PE Notes up to and including PE 666, will be introduced in this and subsequent issues. The main changes are:

Artificial satellites:	551.507.362.2	(PE 657)
Semiconductor devices:	621.382	(PE 657)
Velocity-control tubes, klystrons, etc.:	621.385.6	(PE 634)
Quality of received signal, propagation conditions, etc.:	621.391.8	(PE 651)
Color television:	621.397.132	(PE 650)

The "Extension and Corrections to the UDC," Ser. 3, No. 6, August, 1959, contains details of PE Notes 598–658. This and other UDC publications, including individual PE Notes, are obtainable from The International Federation for Documentation, Willem Witsenplein 6, The Hague, Netherlands or from The British Standards Institution, 2 Park Street, London, W. 1, England.

A list of organizations which have available English translations of Russian journals in the electronics and allied fields appears at the end of the Abstracts and References section.

ACOUSTICS AND AUDIO FREQUENCIES

534.2 1111

Propagation of Acoustic Pulses from a Circular Cylinder—R. G. Barakat. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1759–1764; December, 1961.) The radiation of exponential, sinusoidal and rectangular acoustic pulses by an infinitely long circular cylinder is treated theoretically and their shape at various distances from the cylinder is determined. The passage to the steady state of a semi-infinite sine-wave train is outlined.

534.2:537.56:538.56 1112

Electroacoustic Coupling at the Boundary of an Ionized Medium—Kornhauser. (See 1210.)

534.213.4 1113

Damping of Sound Waves by an Ideally Rough Surface—H. J. Wintle. (*Proc. Phys. Soc. (London), A*, vol. 78, pp. 1265–1267; December 1, 1961.) Results of measurements on a cylindrical rough tube indicate that sound attenuation increases linearly with the numerical measure of roughness of the tube.

534.23 1114

The Influence of the Directivity of Sound Emitters and Receivers on Acoustic Feedback in Sound Amplification Installations—G. Kaszynski. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 141–146; August, 1961.) The sound field distribution and acoustic feedback in enclosed premises are investigated, and laws are formulated for avoiding self-excitation.

534.25 1115

Measurements of Sound Reflection from a Rigid Corrugated Surface—E. O. La Casce, Jr., B. D. McCombe, and R. L. Thomas. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1768–1771; December, 1961.) An examination of the scattering process in the vicinity of cutoff is made using rigid surfaces with sinusoidal corrugations which have a maximum slope near unity. The variation of the specular amplitude with frequency for several angles of incidence is illustrated for two surface wavelengths.

534.24 1116

Some Notes on the Reflection of Sound from a Rigid Corrugated Surface—E. O. LaCasce, Jr. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1772–1777; December, 1961.) The Rayleigh solution for reflection from a corrugated surface, and some possible modifications, are examined.

534.24–8 1117

Demonstration of the 'Least Stable Waveform' of Finite-Amplitude Waves—M. A. Breazeale and W. W. Lester. (*J. Acoust. Soc. Am.*, vol. 33, p. 1803; December, 1961.) "A backward-sloping ultrasonic wave is generated by reflection of a finite-amplitude distorted wave from a pressure-release boundary. The difference between the behavior of this wave and that of a wave distorted in the usual sense is demonstrated."

534.75:621.391 1118

Channel Capacity of the Ear and Optimum Matching of Acoustic Channels—H. Völz. (*Elektron. Rundschau*, vol. 15, pp. 482–488; October, 1961.) The channel capacity of the ear is estimated on the basis of the expression giving the channel capacity of magnetic tape recorders. Using the ear as reference the matching of electroacoustic channels to the ear is considered and limitations of matching systems are discussed. See also 1003 of 1958 (Zwicker).

534.79 1119

Loudness Growth in Binaural Hearing of Complex Noise—H. Niese. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 132–141; August, 1961.) See also 3989 of 1961.

534.84 1120

Formation and Testing of Acoustic Conditions in Rooms—H. Niese. (*Arch. tech. Messen*, pp. 175–176 and pp. 245–248; August and November, 1961.) The acoustic design of auditoria on the bases of statistical and geometric considerations is outlined. Methods of

objective and subjective testing of room acoustics are illustrated in an example.

534.88 1121
Stability of Shot Signals Transmitted through the Deep Ocean—H. B. Sherry and A. Berman. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1790–1792; December, 1961.) Single shots were fired half hourly from a fixed location at a constant depth just below the surface. Signals received 63 miles away at hydrophones 3000 and 9100 feet deep showed a high degree of correlation between successive shots over the test period of 15h.

534.88 1122
Long-Range Localization of Small Underwater Charges—R. A. Frosch, M. Klerer, and L. Tyson. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1804–1805; December, 1961.) Observations were made at twelve stations along the Atlantic coast of U.S.A. of signals from charges exploded up to 3000 miles away. Probable accuracy of the location determinations was within 10 miles.

534.88:621.396.677.3 1123
Directivity of a Linear Array in a Random Transmission Medium—R. C. Bourret. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1793–1797; December, 1961.) "A simple derivation is given of the phase autocorrelation function of a monochromatic signal during transmission through a medium with random fluctuations of refractive index. The resulting phase coherence function is then applied to the theory of the linear array antenna to yield a formula for the degraded directivity pattern."

621.395.61.089.6 1124
Reciprocity Calibration of Electroacoustic Transducers in the Time Domain—A. F. Niemoeller. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1712–1719; December, 1961.) Theoretical considerations in evaluating directly the impulse response of a reciprocal electroacoustic transducer are presented and the experimental method and data-processing procedure are described. The transient response of a coupled pair of identical transducers is used to compute the impulse response of either of the pair.

621.395.625.3 1125
A Study of Interference Effects in Magnetic Recording—J. G. Woodward and M. Pradervand. (*J. Audio Eng. Soc.*, vol. 9, pp. 254–257; October, 1961.) The conditions under which a recording made with a wide recording gap exhibits a series of maxima and minima in its frequency-response characteristic are examined. A qualitative explanation is given.

621.395.625.3 1126
Short-Wavelength Response of Magnetic Reproducing Heads with Rounded Gap Edges—S. Duinker. (*Philips Res. Repts.*, vol. 16, pp. 307–322; August, 1961.) A generalization of Westmijze's results (9 of 1954) and an investigation of the dependence of the gap-length loss factor on the radius of curvature of the gap edges.

ANTENNAS AND TRANSMISSION LINES

621.315.212:621.396.44 1127
An Introduction to the 12.5-Mc/s Coaxial-Line Transmission System—Cameron and Parrett. (See 1401.)

621.372.8:621.391.63 1128
Optical Pipelines: a Tentative Assessment—Eaglesfield. (See 1400.)

621.372.8:621.396.44 1129
The Waveguide as a Means of Transmission for Long-Distance Links—F. Armenante. (*Note Recensioni Notiz.*, vol. 10, pp. 492–529; September/October, 1961.) Review of present state and prospective development of waveguide transmission systems for long-distance communications. 40 references.

621.372.82.011.1 1130
Inclusive Telegraphists Equations for Waveguides—S. Iiguchi. (*Rev. Elec. Comm. Lab., Japan*, vol. 9, pp. 526–535; July/August, 1961.) General equations are derived which are appicable to curved and nonuniform loaded waveguides with inhomogeneities.

621.372.823 1131
Influence of Local Irregularities on the Propagation of a TE_{01} Wave in a Circular Waveguide—G. Comte. (*Onde élect.*, vol. 41, pp. 795–807; October, 1961.) Calculations are made of attenuation, phase and group-delay distortion caused by distributed and by lumped irregularities along a circular waveguide transmitting the TE_{01} mode. Experiments carried out at 35 Gc confirm the theoretical predictions.

621.372.826:621.317.74 1132
A New Measuring Circuit for Dielectric Surface-Wave Transmission Lines—Schulten. (See 1377.)

621.372.831 1133
Matched Transitions between Dissimilar Rectangular Waveguides carrying the H_{10} Mode—J. R. Pyle. (*Proc. IRE (Australia)*, vol. 22, pp. 694–701; November, 1961.) The design, manufacture and performance of a matched transition is described. Approximations necessary for the theoretical development are shown to be reasonable in practice.

621.372.832.6 1134
A 48-Gc/s Centre-Excited-Type Channel Branching Filter for Circular Electric Waves—S. Iiguchi, B. Oguchi, and K. Yamaguchi. (*Rev. Elec. Comm. Lab., Japan*, vol. 9, pp. 421–428; July/August, 1961.) The filter delivers the circular TE_{01} wave of each channel from the main circular waveguide to the appropriate small rectangular guide.

621.372.852.2:538.221 1135
Review of the State of Development of Ferrite Nonreciprocal Microwave Circuit Elements—R. Jähn. (*Nachrtech.*, vol. 11, pp. 352–358 and pp. 409–415; August and September, 1961.) Survey of the application of ferrite devices in coaxial lines and waveguide as phase-shifters, isolators, circulators, etc. 165 references.

621.372.852.323.029.65 1136
Higher Modes in Millimetre-Wave Isolators—P. Vilmur, K. Ishii, and F. F. Y. Wang. (Proc. IRE, vol. 50, pp. 98–99; January, 1962.) A method is described for determining the general field distribution in a mm $-\lambda$ field-displacement isolator. Other observations of the experimental results obtained by this method are noted.

621.396.67:551.507.362:523.164 1137
The Measurements of Random Radio-Frequency Fields by the Use of Short Electric and Magnetic Dipoles—Hugill. (See 1234.)

621.396.673 1138
The Behaviour of Short Linear Aerials on Varying the Distribution of Current—G. D' Auria and F. Todero. (*Alta Frequenza*, vol. 30, pp. 528–542; July, 1961.) English version of 3252 of 1961.

621.396.677:551.507.362.2 1139
Automatic Tracking Antenna for Telstar Communications Satellite—D. F. Shingler. (*Electronics*, vol. 34, pp. 23–27; December 22, 1961.)

621.396.677.3:523.164 1140
Future Large Radio Telescopes—R. N. Bracewell, G. Swarup, and C. L. Seeger. (*Nature*, vol. 193, pp. 412–416; February 3, 1962.) The construction of interferometers with their facility for subsequent extension is preferred. Means of eliminating grating responses are described and the use of the n beams of the array of n receiving systems to reduce observing time by a factor of n is suggested. 32 references.

621.396.677.3:534.88 1141
Directivity of a Linear Array in a Random Transmission Medium—Bourret. (See 1123.)

621.396.677.3:621.396.712 1142
The Selection of the Optimum Curtain Array for a High-Frequency Broadcasting Service—P. Knight. (*Proc. IEE*, pt. B, vol. 109, pp. 91 98; January, 1962.) The field strength produced by curtain arrays has been calculated and plotted as a function of distance from the receiving site.

621.396.677.71 1143
Long-Slot Aerials—T. Heller. (*Nachrtech. Z.*, vol. 14, pp. 441–444; September, 1961.) The use as a radiator of a slot cut into the narrow side of a waveguide is discussed and investigated experimentally. A method is given for obtaining specified radiation patterns.

621.396.677.833:523.164 1144
The Australian 210-ft Radio Telescope—E. G. Bowen and H. C. Minnett. (*J. Brit. IRE*, vol. 23, pp. 49–54; January, 1962. Discussion.) The paraboloid has an f/D ratio of 0.41, and surface error should be less than ± 9 mm. The mounting is of the altazimuth type, and the over-all pointing accuracy is expected to be within a 1 minute arc.

AUTOMATIC COMPUTERS

681.142:621.318.57:537.312.62 1145
A Cryotron Memory Cell—A. E. Slade. (Proc. IRE, vol. 50, pp. 81–82; January, 1962.) An improved versatile storage cell consisting of three cryotrons and one superconductive loop is described.

681.142:621.318.57:621.382 1146
High-Speed Logic Circuits using Common-Base Transistors and Tunnel Diodes—J. Amodei and W. F. Kosonocky. (*RCA Rev.*, vol. 22, pp. 669–684; December, 1961.)

681.142:621.374.5 1147
Digital Function Generation with Torsional Delay Lines—W. Perzley and M. Fishbein. (*Electronics*, vol. 35, pp. 62–65; January 12, 1962.) A torsional magnetostriction delay line has small magnets to replace the usual control taps. Since the magnets do not load the line, a large number of taps, each equivalent to one bit, may be used with one common output.

681.142:621.376.222 1148
Envelope Feedback in an Audio-Frequency Amplitude Modulator—W. D. Humpage. (*Electronic Eng.*, vol. 34, pp. 96–98; February, 1962.) The amplitude modulator is designed to transmit solution information when a composite computing scheme consisting of an analog computer and a network analyzer is used to solve problems concerning generator and load transients.

681.142:621.382.333 1149
The Logic Potential of Molecular Electronics in the Multicollector Transistor—J. Earle. (*Elec. Engrg.*, vol. 80, pp. 525–533; July, 1961.) Methods of applying the tech-

niques of molecular electronics to form logic circuits are discussed, with emphasis on the two-collector transistor [see 315 of 1958 (Rutz)]; the logical effects of more collectors are briefly considered.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049 1150

Microsystems and Molecular Electronics—(*Elect. Engrg.*, vol. 80, pp. 482–542; July, 1961.) A special issue containing nine papers describing the need for microsystems and designs for modular and solid-state circuits. The last three papers are abstracted separately.

621.3.049:539.23 1151

Microsystem Circuit Analysis—P. S. Castro. (*Elect. Engrg.*, vol. 80, pp. 535–542; July, 1961.) A general method for analyzing filmtype networks, based on the theory of indefinite matrices, is presented. Simple rules are developed for generating subnetworks from a given four-terminal network.

621.3.049.75:620.178.3 1152

A Fatigue Test for Printed Wiring Boards and Through-Connections—G. R. Gohn and A. Fox. (*Mater. Res. Stand.*, vol. 1, pp. 711–716; September, 1961.) A Krouse flat-plate fatigue testing machine was modified to take the larger specimens to be examined. Typical test data are presented in the form of strain-cycle/life diagrams.

621.318:538.632 1153

Developing the Hall Generator Equivalent Circuit—J. W. Motto, Jr. (*Electronics*, vol. 35, pp. 90–92; January 5, 1962.) The basic phenomena occurring in the device are described in matrix form and an equivalent circuit is derived by matrix manipulation. Current gain, voltage gain and input impedance are found in terms of the equivalent-circuit parameters.

621.318.4:539.23 1154

Nonlinear and Controllable Inductances made of Thin and Magnetic Films—K. Sabban. (*Z. angew. Phys.*, vol. 13, pp. 420–425; September, 1961.) The inductance considered, which may be used for parametric amplification, takes the form of a thin ferromagnetic film in a magnetizing coil. The effect of film premagnetization on the inductance value is calculated. Experimental results obtained for a $\lambda/4$ coaxial oscillator system are compared with theory.

621.318.57:621.374.32 1155

Ferrite-Core Current-Steering Commutators and Ring Counters—H. J. Andrews. (*Proc. IEE*, pt. B, vol. 109, pp. 84–90; January, 1962.) Commutating circuits are described which steer well-defined current pulses sequentially along a number of paths, and simplified design formulas are given.

621.318.57:681.142 1156

Duality Relations between Threshold-Type Switching Functions and their Application to Problems of Synthesis—L. Dadda. (*Alta Frequenza*, vol. 30, pp. 572–574; August, 1961.) For English version see *Alta Frequenza*, vol. 30, pp. 837–839; December, 1961.

621.319.42:539.23 1157

Thin-Film Capacitors using Tantalum Oxide Dielectrics Prepared by Reactive Sputtering—P. Lloyd. (*Solid-State Electronics*, vol. 3, pp. 74–75; July, 1961.) A note on the method of preparation and measured characteristics.

621.372.4/.5:621.376.4 1158

The Transient Response of Linear Passive Networks to Phase-Modulated Signals—J. M. Ivison. (*Electronic Eng.*, vol. 34, pp. 87–91; February, 1962.) Some simple networks are stimulated by a sinusoidal signal, phase modulated by a step input. Analytical solutions are verified experimentally and with an analog computer.

621.372.44 1159

Parametric Behaviour of an Ideal Two-Frequency Varactor—G. F. Montgomery. (Proc. IRE, vol. 50, pp. 78–80; January, 1962.) An analysis in which pump and signal voltages of large amplitude are allowed, and the complete varactor characteristic is used. With linear signal termination, the ratio of signal to pump frequency must be $M/2$ where M is an integer. All possible operating modes are identified.

621.372.5 1160

A Synthesis Procedure—J. B. Rudd. (*AWA Tech. Rev.*, vol. 11, pp. 203–219; September, 1961.) The synthesis of symmetrical reactance networks with equal termination is considered. From the insertion loss characteristic, the impedance which the half-circuit presents at the axis of symmetry is derived from network theory (3269 of 1961) and the complete circuit is obtained by back-to-back connection of the two halves.

621.372.54 1161

The Representation of Ladder-Network Parameters through Continued-Fraction Polynomials—A. W. Thies. (*Aust. J. Appl. Sci.*, vol. 12, pp. 371–392; December, 1961.) Euler polynomials are used to derive concise expressions for the transmission parameters of linear ladder networks in terms of the branch and terminating immittances. A generalized form of the polynomials is helpful in the design of reactively coupled multiple-tuned narrow band-pass filters.

621.372.543.2 1162

Band-Pass Filters having Quasi-Symmetrical Attenuation and Group-Delay Characteristics—F. Carassa. (*Alta Frequenza*, vol. 30, pp. 488–499; July, 1961. In English.) Description of design procedure and report on experimental results. For Italian version see *Alta Frequenza*, vol. 30, pp. 643–655; September, 1961.

621.372.57:621.3.029.4 1163

Integrating and Differentiating Circuits (Applications to Filtering and to Acoustics)—P. Brun. (*Ann. Phys. (Paris)*, vol. 6, pp. 795–850; plates. July/August, 1961.) The basic circuits and the effect of successive operations on speech and music signals are considered. A detailed study is made of an IF band-stop filter derived by linear combination of differentiating and integrating circuits. Its applications in a distortion meter, selective amplifier and DF oscillator are described.

621.372.632:538.221:621.318.134 1164

Harmonic Generation and Frequency Mixing in Ferromagnetic Insulators—R. L. Jepsen. (*J. Appl. Phys.*, vol. 32, pp. 2627–2630; December, 1961.) Calculations are made of second-harmonic generation and second-order frequency mixing for small ellipsoidal samples, with loss included in the Landau-Lifshitz form. Examples are given and a simple case of third-harmonic generation is discussed. Detailed calculations are given elsewhere.

621.373:621.391.822 1165

Background Noise in Oscillators with R.F. Pushing—J. A. Mullen. (*J. Electronics and Control*, vol. 10, pp. 127–138; February, 1961.) An extension of previous work (*e.g.*, 3751 of 1960) to include nonlinearities in which the frequency of oscillation is a function of oscillation amplitude.

621.373.001.1 1166

An Indirect Method for the Exact Solution of the Oscillator Equation—R. Codelupi. (*Alta Frequenza*, vol. 30, pp. 556–563; August, 1961.) By establishing the characteristic of the oscillator in the phase plane exact solutions of the nonlinear differential equation involved can be found. The characteristics of these solutions are discussed. For English version see *Alta Frequenza*, vol. 30, pp. 500–507; July, 1961.

621.373.431.1.072.6:621.318.57 1167

Transfluxor Frequency Memory—A. G. Samusenko. (*RCA Rev.*, vol. 22, pp. 658–668; December, 1961.) A transfluxor is used as the frequency-control component of a magnetically coupled multivibrator.

621.373.43:621.382.3 1168

Sawtooth Generator with Almost Infinite Linearity—V. Spány. (*Elektron. Rundschau*, vol. 15, pp. 531–534; November, 1961.) The Miller integrator using junction transistors is analyzed; maximum linearity is achieved with the transistor operating without feedback in an earthed-base circuit. Practical circuits for generating various sawtooth waveforms are given.

621.373.444:621.382.3 1169

An Analysis of the D.C. Design Considerations of a Transistorized Schmitt Trigger: Parts 1 & 2—J. Corsiglia. (*Semiconductor Prod.*, vol. 4, pp. 29–32 and pp. 23–27; November and December, 1961.) Design difficulties are reduced by establishing first the necessary and second the desirable requirements, so that the number of variable parameters is minimized.

621.373.5 1170

Voltage-Controlled Wide-Range Oscillator—R. A. Greiner and S. K. Morgan. (*Electronics*, vol. 34, pp. 31–35; December 22, 1961.) The variation of the small-signal impedance of a junction diode with bias is used to give voltage-controlled phase shift.

621.374 1171

Study of Transients in Similar Electrical Networks—L. Lunelli. (*Alta Frequenza*, vol. 30, pp. 564–571; August, 1961.) The transient characteristics of equivalent *RCL* networks obtained by frequency or impedance transformation are analyzed. For English version see *Alta Frequenza*, vol. 30, pp. 718–725; October, 1961.

621.374.32 1172

New High-Speed Counter-Divider—H. W. Hawkes. (*Electronic Tech.*, vol. 39, pp. 48–55; February, 1962.) The unit will count and divide by any number up to 1000 at 450 kc. Operation at frequencies up to 10 Mc should be possible.

621.374.32:621.318.042.1:539.23 1173

A Self-Indicating Magnetic Scaling System using Electro-deposited Nickel-Iron Film Cores—E. Franklin. (*J. Brit. IRE*, vol. 23, pp. 69–79; January, 1962.) Details are given of a magnetic decade scaling system in which direct count indication is obtained by using the external magnetic fields of the storage cores themselves. With the electrodeposition technique described the difficulty of getting sufficiently close coupling between the film and the associated driving and sense coils has been overcome.

621.374.4:621.372.44 1174

Theory, Design and Performance of Maximum-Efficiency Variable-Reactance Frequency Multipliers—T. Utsunomiya and S. Yuan. (Proc. IRE, vol. 50, pp. 57–65; January, 1962.) The maximum efficiency with a given nonlinear element and circuitry is predicted from the analysis, and circuit configurations for im-

proved efficiency at a given harmonic are indicated.

621.375.4 1175
Choice of Collector Load Resistance for Minimum Harmonic Distortion—Y. Azar. (*Electronic Eng.*, vol. 34, pp. 108–110; February, 1962.) A graphical method for calculating the optimum load to minimize harmonic distortion in transistor amplifiers.

621.375.4 1176
The Earthed-Collector Circuit as an Amplifier with High Input Impedance—E. Pfeiffer and O. Gentner. (*Elektron. Rundschau*, vol. 15, pp. 478–482; October, 1961.) The earthed-collector circuit configuration is analyzed and expressions are obtained for its input impedance and frequency response. Calculated and measured results are compared and circuit stability limits are discussed.

621.375.4.029.62 1177
Wide-Band Amplifiers, Tuned or Aperiodic, using Transistors up to 250 Mc/s—J. M. Colin. (*Ann. Phys.* (*Paris*), vol. 6, pp. 913 947; July/August, 1961.) Stabilization of circuits against varying ambient temperature, frequency compensation in aperiodic amplifiers, design of distributed amplifiers, and gain control of tuned amplifiers are examined.

621.375.9:538.569.4 1178
Adiabatic Rapid Passage in Ruby at 8-mm Wavelengths—J. S. Thorp, J. H. Pace, and D. F. Sampson. (*J. Electronics and Control*, vol. 10, pp. 13–24; January, 1961.) Performance data are given on a two-level ruby maser operating at 1.4°K with a modulated magnetic field, and using the crystal as a resonant cavity. As an amplifier it has a gain of 14 db and bandwidth 10 Mc; as an oscillator it has an output of 70 μw at 31.1 Gc.

621.375.9:538.569.4 1179
A CW Solid-State, Push-Pull Maser in the 5- to 6-Millimetre Wavelength Region—D. L. Carter. (*J. Appl. Phys.*, vol. 32, pp. 2541–2542; December, 1961.) "C.w. master oscillation from 49 to 57 Gc/s was achieved with 0.12% Fe^{3+}-doped rutile, using push-pull pumping at 78.2 Gc/s. A short experiment on cross-relaxation effects was also performed."

621.375.9:538.569.4 1180
Magnetic Perturbation of an Ammonia Maser on the 3,2 Line—K. Shimoda. (*J. Phys. Soc. Japan*, vol. 16, pp. 2270–2282; November, 1961.) Theoretical curves of frequency change as a function of the perturbing field are given for a 3,2-line NH_3 maser (426 of February). Fluctuations of the field by 10 per cent are shown to give an error of about 10^{-11}.

621.375.9:538.569.4 1181
Dependence of Magnetic Coupling Constant of Ammonia on the Inversion State—K. Shimoda. (*J. Phys. Soc. Japan*, vol. 16, pp. 2283–2287; November, 1961.) Theoretical studies indicate that in a 3,2-line NH_3 maser the magnetic coupling constants of the upper and lower inversion states are different, resulting in the observed dependence of frequency on magnetic field.

621.375.9:538.569.4:621.3.018.41(083.74) 1182
$N^{15}H_3$ Double-Beam Maser as a Primary Frequency Standard—De Prins, Menoud, and Kartaschoff. (See 1369.)

621.375.9:621.372.44:621.372.632 1183
Theory and Design of Wide-Band Parametric Converters—E. S. Kuh. (PROC. IRE, vol. 50, pp. 31–38; January, 1962.) A circuit-theory approach using a linear time-varying capacitance with a linear passive network.

621.375.9:621.372.44:621.382.23 1184
Diffused Silicon Mesa Diodes for Use in Refrigerated Parametric Amplifiers—Forster and Uenohara. (See 1427.)

621.375.9:621.372.44:621.385.6 1185
Analysis of Fast-Wave Couplers for Transverse-Field Beam-Type Parametric Amplifiers—N. B. Chakraborty. (*J. Electronics and Control*, vol. 10, pp. 147–151; February, 1961.)

621.375.9:621.372.44:621.385.6 1186
The Application of Beam Cooling to Quadrupole Amplifiers—Lea-Wilson, Bridges, and Vokes. (See 1445.)

621.375.9:621.372.44:621.391.822 1187
Quantum Fluctuations and Noise in Parametric Processes: Part I—W. H. Louisell, A. Yariv, and A. E. Siegman. (*Phys. Rev.*, vol. 124, pp. 1646–1654; December 15, 1961.) "A quantum mechanical model for parametric interactions is used to evaluate the effect of the measuring (amplifying) process on the statistical properties of radiation. Parametric amplification is shown to be ideal in the sense that it allows a simultaneous determination of the phase and number of quanta of an electromagnetic wave with an accuracy which is limited only by the uncertainty principle. Frequency conversion via parametric processes is shown to be free of zero-point fluctuations."

621.376.22:621.315.212 1188
Rapid Modulation of (*S*-Band) Microwaves on a Coaxial Line with the Aid of Ferrites—H. Place. (*J. phys. radium*, vol. 22, pp. 730–731; October, 1961.) A 3-Gc signal on a coaxial cable has been modulated to a depth of 15 per cent at 10.4 Mc. Resonance absorption in a magnetized ferrite tube threaded on the core of the cable is varied by a coil round the tube. The modulating field is chosen to operate about a mean value on one flank of the resonance curve.

621.376.3 1189
Decreasing the Threshold in F.M. by Frequency Feedback—L. H. Enloe. (PROC. IRE, vol. 50, pp. 18–30; January, 1962.) The feedback action of the demodulator is taken nto account in determining the threshold; calculated values agree well with experimental data.

621.376.4 1190
An Automatic-Frequency-Controlled Phase-Shift-Keyed Demodulator—W. Hannan and T. Olson. (*RCA Rev.*, vol. 22, pp. 729–752; December, 1961.) The principles of demodulators with binary phase-shift keying are reviewed. Design equations are given which indicate the "trade-off" relations between pull-in range, noise bandwidth and lock-up time. Experimental results are given.

GENERAL PHYSICS

535.1 1191
Correlation in the Fluctuating Outputs from Two Square-Law Detectors Illuminated by Light of Any State of Coherence and Polarization—L. Mandel and E. Wolf. (*Phys. Rev.*, vol. 124, pp. 1696–1702; December 15, 1961.) The correlation is found by treating light fluctuations as a random process. The expression takes a particularly simple form when the light is spectrally pure. Two special cases are applicable to the Hanbury Brown-Twiss effect (see *e.g.*, 1666 of 1956) and to correlation experiments with light from optical masers.

535.215+535.37 1192
Thermally Stimulated Emission and Conductivity Peaks in the Case of Temperature-Dependent Trapping Cross-Sections—P. N. Keating. (*Proc. Phys. Soc.* (*London*) *A*, vol. 78, pp. 1408–1415; December 15, 1961.) Original theory is extended and a method is proposed for determining by a single experiment the ionization energy and temperature-dependent cross section of a trapping level.

535.37 1193
Stimulated Emission into Optical Whispering Modes of Spheres—C. G. B. Garrett, W. Kaiser, and W. L. Bond. (*Phys. Rev.*, vol. 124, pp. 1807–1809; December 15, 1961.) "Stimulated emission into optical whispering modes of a spherical sample of CaF_2:Sm^{++} has been observed. Light produced by the stimulated emission is radiated tangentially from each point on the surface of the sphere. The experimental results have been interpreted in terms of the electromagnetic analog of the Rayleigh theory of the whispering gallery."

535.5:538.566.2 1194
Modes in Sequences of Lenses—J. R. Pierce. (*Proc. Nat'l Acad. Science*, vol. 47, pp. 1808–1813; November 15, 1961.) An investigation of the modes of propagation of coherent light in a sequence of lenses.

537.311.33 1195
Quantum Theory of Free-Carrier Absorption—W. P. Dumke. (*Phys. Rev.*, vol. 124, pp. 1813–1817; December 15, 1961.) Quantum theory becomes equivalent to classical Boltzmann theory for photon energies small compared to carrier energies.

537.311.33 1196
Collective Behaviour in Solid-State Plasmas—D. Pines and J. R. Schrieffer. (*Phys. Rev.*, vol. 124, pp. 1387 1400; December 1, 1961.) Theoretical investigation of the nonlinearities in plasma wave instability applied particularly to the possibility of observing this effect in InSb. Scattering mechanisms may prevent observation.

537.311.33:538.63 1197
Instabilities of a Cylindrical Electron-Hole Plasma in a Magnetic Field—M. Glicksman. (*Phys. Rev.*, vol. 124, pp. 1655–1664; December 15, 1961.) The stability of an electron-hole plasma carrying current parallel to a magnetic field is investigated. Instabilities are predicted and the calculated values of electric field, magnetic field and lowest oscillation frequency are compared with available observations. Agreement is reasonably satisfactory.

537.311.33:538.632 1198
Hall Effect in Impurity Conduction—T. Holstein. (*Phys. Rev.*, vol. 124, pp. 1329–1347; December 1, 1961.) The existence of a nonvanishing Hall effect in the "impurity conduction" regime of a semiconductor is demonstrated. The theory is based on a three-site transition process and in particular on a magnetic-field-dependent contribution to the jump probability between two sites.

537.525 1199
A Microwave Plasma Discharge—J. Allison, A. L. Cullen and A. Závody. (*Nature*, vol. 193, p. 156; January 13, 1962.) Striae produced in argon by high-power CW 3.4-cm-λ radiation are described and illustrated. Their maximum length was 10–15 cm, and width 1–2 mm.

537.525 1200
Time-Lags Associated with Ultra-High Frequency Gas Breakdown—W. A. Prowse, J. R. Rowbotham, and P. G. Monk. (*Proc. Phys. Soc.* (*London*) *A*, vol. 79, pp. 158–170; January 1, 1962.) An investigation of the time-lags associated with gas breakdown in correctly profiled parallel-plate gaps at a frequency of 183 Mc.

537.525:538.69 1201
Magnetically Confined Cold-Cathode Gas Discharges at Low Pressures—R. L. Jepsen. (*J. Appl. Phys.*, vol. 32, pp. 2619–2626; December, 1961.) A theory is developed taking account of the effects of space charge in inverted and in normal magnetrons and in Penning structures. Discharges of much greater intensity may be expected in normal magnetrons than in inverted magnetrons.

537.525.08 1202
Electron Energy Distribution Measurements in Gas Discharges—B. W. Smithers. (*J. Sci. Instr.*, vol. 39, pp. 21–22; January, 1962.) Accuracy of the distribution determination using the d^2I/dV^2 method of Druyvestyn is improved by differentiating the Langmuir-probe signal and filtering mains-frequency noise from the dI/dV output. The second differential coefficient is obtained by graphical differentiation.

537.533 1203
Brillouin Flow in Relativistic Beams—D. C. dePackh and P. B. Ulrich. (*J. Electronics and Control*, vol. 10, pp. 139–146; February, 1961.) A solution in closed form in a cylindrical geometry is derived in the limit of low beam temperature.

537.533 1204
Exact Solution of the One-Dimensional Bunching Problem—L. Solymar. (*J. Electronics and Control*, vol. 10, pp. 165–180; March, 1961.) A solution is derived for the bunching of an infinite electron beam modulated by an infinitesimal gap. The solution is valid when no overtaking occurs.

537.533 1205
Theory of the Potential Well Produced by Multipacting Electrons: Part 1—Very-Low-Pressure Regime—R. L. Ingraham. (*J. Appl. Phys.*, vol. 32, pp. 2553–2558; December, 1961.) Theory of ion behavior in an "electron well."

537.533 1206
The Transverse Electric Noise from an Electron Beam—F. N. H. Robinson and R. N. Franklin. (*J. Electronics and Control*, vol. 10, pp. 277–284; April, 1961.) The measurement of transverse noise provides a means of investigating scattering phenomena.

537.533:537.56 1207
Analysis of Double-Stream Interactions in the Presence of a Finite Axial Magnetic Field—B. Vural. (*RCA Rev.*, vol. 22, pp. 753–779; December, 1961.) Couplings of fast and slow cyclotron and space-charge waves, between two electron beams, and between an electron beam and a plasma are analyzed.

537.56 1208
Fluctuations in a Plasma: Part 1—Ion-Electron Temperature Relaxation—O. Aono. (*J. Phys. Soc., Japan*, vol. 16, pp. 2264–2270; November, 1961.) The rate of relaxation calculated on the basis of the fluctuation-dissipation theorem, assuming interaction between the ion and the fluctuating electric field caused by the surrounding electrons, is found to agree with the result obtained considering interactions with individual electrons [*J. Phys. Soc. Japan*, vol. 15, pp. 684–687; April, 1960. (Kihara, *et al.*)].

537.56:538.56 1209
The Behaviour of a Plasma Under the Influence of a Standing Electromagnetic Wave in the Absence of a Constant Magnetic Field—J. W. Gallop, T. L. Dutt and H. Gibson. (*J. Electronics and Control*, vol. 10, pp. 207–240; March, 1961.) The physics of the radial confinement of an ionized plasma in an em field are examined for a cylindrical cavity excited in the TM_{010} and TE_{011} modes.

537.56:538.56:534.2 1210
Electroacoustic Coupling at the Boundary of an Ionized Medium—E. T. Kornhauser. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1764–1767; December, 1961.) An analysis is developed to explain the production of a reflected sound wave and a transmitted modified sound wave at the boundary of an ionized medium when an em wave is incident at the boundary in the presence of a transverse magnetic field.

537.56:538.566:621.372.413 1211
A Proposal to Use Microwave Cavities to Study the Surface Properties of High-Density Plasmas—F. L. Curzon and R. Howard. (*Canad. J. Phys.*, vol. 39, pp. 1901–1910; December, 1961.) The method is based on the resonance properties of a cavity containing a highly conductive axial plasma rod.

537.56:538.566:621.372.413 1212
A Method of Measuring the Potential Distribution in a Cylindrical R.F. Cavity containing Plasma—E. D. Dracott. (*J. Electronics and Control*, vol. 10, pp. 25–32; January, 1961.) An ion beam is directed through the plasma and the position, velocity and direction of the beam at the points of entry and exit are determined. By varying the input parameter, the potential of a particular point inside the plasma can be computed.

537.56:538.63 1213
Magnetocompressional Disturbance in a Tepid Plasma—P. L. Auer and J. A. Nation. (*Nuovo Cim.*, vol. 22, pp. 533–547; November 1, 1961. In English.) The examination of steady-state pulses traveling at right angles to a magnetic field in a cold plasma [1162 of 1959 (Adlam and Allen)] is extended to a tepid plasma. A linear and quasi-nonlinear analysis is given from which it is shown that pulses exist when the disturbance speed is supersonic.

537.56:621.317.3 1214
A Method for Measuring the Conductivity in a High-Electron-Density Plasma—K. B. Persson. (*J. Appl. Phys.*, vol. 32, pp. 2631–2640; December, 1961.) The interaction between the solenoidal electric field and a circular cylindirical plasma column is used as the basis for the design of a pulse-operated bridge suitable for transient measurements of conductivity in high-density plasma.

538.114 1215
The Ferromagnetism of the Plane Lattice—W. Doring. (*Z. Naturforsch.*, vol. 16a, pp. 1008–1016; October, 1961.) Inconsistencies in the results of the theoretical treatment of ferromagnetism at low temperatures on the basis of the Heisenberg model are discussed.

538.114 1216
Theory of Direct Exchange in Ferromagnetism—A. J. Freeman and R. E. Watson. (*Phys. Rev.*, vol. 24, pp. 1439–1454; December 1, 1961.) A unique definition of J is applied to the following cases on a Heisenberg atomic model: a) hydrogen $3d$ functions; b) $3d$ orbitals of the iron-series; c) a pair of iron series atoms in a $3d^9$ configuration. It is found to be negative in all cases. The conclusion is that the direct-exchange model is inadequate or inappropriate.

538.221:534.28 1217
Mechanical Damping due to Magnetic Processes—H. Franz. (*Z. Metallkde*, vol. 53, pp. 27–37; January, 1962.) The causes of magnetic damping are analyzed with reference to theoretical and experimental investigations by various authors. The technical implications of these effects are discussed. 91 references.

538.24 1218
Anisotropic Curie Temperature—E. R. Callen. (*Phys. Rev.*, vol. 124, pp. 1373–1379; December 1, 1961.) A theoretical treatment showing how the Curie temperature in an anisotropic ferromagnet varies with the direction of magnetization.

538.566+534.2 1219
Momentum and Energy of Waves—J. R. Pierce. (*J. Appl. Phys.*, vol. 32, pp. 2580–2584; December, 1961.) Elementary arguments of conservation of energy and momentum are used to derive expressions for the "formal" momentum, angular momentum and energy of a plane wave in a moving medium.

538.566:535.42 1220
High-Frequency Diffraction by a Wedge with a Linearly Varying Surface Impedance—L. B. Felsen. (*Appl. Sci. Res.*, vol. B9, no. 3, pp. 170–188; 1961.) An asymptotic representation, valid both in the illuminated and shadow regions, is derived for the scattered field due to an incident plane wave, and its properties are analyzed as a function of the rate of variation of surface impedance.

538.569 1221
Absorption of Electromagnetic Radiation by an Electron Gas—N. Tzoar and A. Klein. (*Phys. Rev.*, vol. 124, pp. 1297–1306; December 1, 1961.) Using the Green's function formulation of the many-body problem, the total absorption cross section for a photon by an electron gas is calculated in the high-density limit.

538.569.4:535.853 1222
Pulsed *X*-Band E.P.R. Spectrometer—D. E. Kaplan, M. E. Browne and J. A. Cowen. (*Rev. Sci. Instr.*, vol. 32, pp. 1182–1186; November, 1961.) A description of the design and operation of an electron-paramagnetic-resonance spectrometer for observation of spin echoes in the submicrosecond time domain.

538.569.4:535.853 1223
Radio-Frequency Spectrometer with Bi-directional Square-Wave Frequency Modulation—J. F. Verdieck and C. D. Cornwell. (*Rev. Sci. Instr.*, vol. 32, pp. 1383–1386; December, 1961.) Modulation is effected by means of a voltage-controlled Si capacitor coupled to the oscillator tank circuit. If the frequency deviation is greater than the line width the absorption line will be displayed with full available intensity and good shape. By careful adjustment of the relative amplitude of the positive- and negative-going deviations, incidental amplitude modulation in the RF detector output component can be eliminated. This method should be applicable to other types of spectrometers.

538.569.4:535.853 1224
Spectrometer for the Frequency Range 100 to 300 Mc/s—R. C. La Force. (*Rev. Sci. Instr.*, vol. 32, pp. 1387–1389; December, 1961.) The instrument incorporates a Hartley-type marginal oscillator with continuous frequency sweep and frequency modulated at a repetition rate of 30 cps.

538.569.4:537.228.5:535.853 1225
A Stark-Effect Microwave Spectrograph with High Resolving Power—H. D. Rudolph. (*Z. angew. Phys.*, vol. 13, pp. 401–409; September, 1961.) Description of a spectrograph incorporating a carcinotron as microwave source and using 30-kc Stark-effect modulation.

538.569.4:621.375.9:535.61-1 1226
Optical Maser Characteristics of TM^{+3} in $CaWO_4$—L. F. Johnson, G. D. Boyd, and K. Nassau. (PROC. IRE, vol. 50, pp. 86–87; January, 1962.)

538.569.4:621.375.9:535.61-1 1227
Optical Maser Characteristics of Ho^{+3} in $CaWO_4$—L. F. Johnson, G. D. Boyd and K. Nassau. (PROC. IRE, vol. 50, pp. 87–88; January, 1962.)

538.569.4:621.375.9:535.61-2 1228
Optical Maser Action of Nd^{+3} in a Barium Crown Glass—E. Snitzer. (*Phys. Rev. Lett.*, vol. 7, pp. 444–446; December 15, 1961.) A glass optical maser using ND^{+3} ions and operating at room temperature is described. A number of sharp lines are emitted in a 30-Å range centered about 1.06 μ.

538.569.4:621.375.9:535.61-2 1229
On the Resonant Frequency Modes of Ruby Optical Masers—M. Ciftan, A. Krutchkoff, and S. Koozekanani. (PROC. IRE, vol. 50, pp. 84–85; January, 1962.) Using a high-resolution spectrograph in conjunction with a Fabry-Perot interferometer of high resolving power, shows the output from an optical maser to consist of lines. At higher input energies more modes are excited.

539.2 1230
The Kinetics of Moving Phase Boundaries in Ferromagnetic, Ferroelectric and Superconducting Materials—A. C. Sim. (*J. Electronics and Control*, vol. 10, pp. 97–116; February, 1961.) The inadequacy of previously published theories is discussed. A phenomenological model is considered in which a phase boundary is represented by a thin sheet of the material in an intermediate state.

539.2:537.311.33 1231
Inverted Nature and Significance of Negative-Mass Landau Levels—G. C. Dousmanis. (*Phys. Rev.*, vol. 124, pp. 1417–1422; December 1, 1961.)

539.2:538.214 1232
The Magnetic Susceptibility of an Electron Gas—M. J. Stephen. (*Proc. Roy. Soc.* (*London*) *A*, vol. 265, pp. 215–228; January 23, 1962.) The cluster expansion of the quantum-mechanical grand partition function is obtained for a gas of interacting charged particles in a uniform magnetic field and applied to calculate the susceptibility of an electron gas for small fields.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.152.3 1233
Measurement of Interplanetary Electron Density from the Earth—M. J. Buckingham. (*Nature*, vol. 193, pp. 538–539; February 10, 1952.) Radio astronomy techniques for density measurement in free space, the solar corona and the lunar electron atmosphere are discussed and a solar-wind plasma model is examined.

523.164:551.507.362:621.396.67 1234
The Measurements of Random Radio-Frequency Fields by the Use of Short Electric and Magnetic Dipoles—J. Hugill. (*Planet-Space Sci.*, vol. 8, pp. 68–70; November, 1961.) A note on the relation between measured noise voltages at the terminals of a short antenna and the temperature of the radiation field, with reference to satellite measurements of sky brightness [2566 of 1961 (Molozzi, *et al.*)].

523.164:621.396.677.3 1235
Future Large Radio Telescopes—Bracewell, Swarup, and Seeger. (See 1140.)

523.164:621.396.677.833 1236
The Australian 210-ft Radio Telescope—Bowen and Minnett. (See 1144.)

523.164.32:523.75 1237
Bursts of Centimetre-Wave Emission and the Region of Origin of X Rays from Solar Flares—M. R. Kundu. (*J. Geophys. Res.*, vol. 66, pp. 4308–4312; December, 1961.) Seven solar flare events are discussed. X-ray emission is found to be closely associated with cm-λ emission; less closely with m-λ emission. Some implications are considered.

523.164.4 1238
The Radio Emission from Normal Galaxies: Part 3—Observations of Irregular and Early-Type Galaxies at 158 Mc/s and a General Discussion of the Results—R. H. Brown and C. Hazard. (*Monthly Notices Roy. Astron. Soc.*, vol. 123, no. 3, pp. 279–283; 1961.) Part 2: 473 of February.

523.164.4 1239
Extragalactic Radio Emission at 4.8 Mc/s—G. R. A. Ellis. (*Nature*, vol. 193, pp. 258–259; January 20, 1962.) Report and discussion of some results of an interferometer survey of the sky at Hobart, Tasmania.

523.1.164.4 1240
Radio Emission from Cassiopeia 23N5A on 130-cm Wavelength—A. Tlamicha. (*Nature*, vol. 193, p. 261; January 20, 1962.)

523.165 1241
Time Variations of Directional Cosmic-Ray Intensity at Low Latitudes—U. R. Rao and V. Sarabhai. (*Proc. Roy. Soc.* (*London*) *A*, vol. 263, pp. 101–135; August 22, 1961.)

Part 1: Comparison of Daily Variation of the Intensity of Cosmic Rays incident from East and West.

Part 2: Time Variations of East-West Asymmetry.

Part 3: Interpretation of Solar Daily Variation and Changes of East-West Asymmetry.

A report of investigations conducted at Ahmedabad during 1957 and 1958.

523.165 1242
On a Short-Lived Cosmic-Ray Decrease on November 13, 1960—I. Escobar, N. W. Nerurkar, O. Troncoso, and M. Zubieta. (*Proc. Nat'l Acad. Science*, vol. 47, pp. 1873–1875; December 15, 1961.)

523.165 1243
Observations of the Van Allen Radiation Regions during August and September 1959: Part 2—The Capetown Anomaly and the Shape of the Outer Belt—R. A. Hoffman. (*J. Geophys. Res.*, vol. 66, pp. 4003–4006; December, 1961.) The position of the relative minimum in the outer belt as found by Explorer VI differs significantly from the position calculated for particles affected by the Capetown anomaly. Part 1: 3474 of 1960 (Arnoldy, *et al.*).

523.165 1244
Geomagnetically Trapped Electrons from Cosmic-Ray Albedo Neutrons—A. M. Lenchek, S. F. Singer, and R. C. Wentworth. (*J. Geophys. Res.*, vol. 66, pp. 4027–4046; December, 1961.) The energy spectrum for outer-belt electrons derived from a neutron albedo source is calculated. The spectrum peaks at 200 kev whereas rocket results indicate no such peak. There is fair agreement above 400 kev. Only the small fraction of electrons above 400 kev can be accounted for by a neutron albedo source. The Capetown anomaly is found to give only a 2 per cent relative minimum in the equatorial plane compared with the 20 per cent observed.

523.165 1245
Solar Proton Impact Zones—T. Kelsall. (*J. Geophys. Res.*, vol. 66, pp. 4047–4070; December, 1961.) The trajectories of charged particles in a magnetic dipole field are calculated numerically and applied to data on the intensity variation of cosmic rays during recent solar events. The relative number of impacts in the northern and southern geomagnetic hemispheres depends strongly on season. Low-energy protons are focused into small impact areas on the earth.

523.165 1246
Supernovae as Cosmic-Ray Sources—M. M. Shapiro. (*Science*, vol. 135, pp. 175–193; January 19, 1962.) A theory explaining the origin of primary cosmic rays is proposed.

523.165:550.385.4 1247
Cosmic-Ray Evidence for a Ring Current—P. J. Kellogg and J. R. Winckler. (*J. Geophys. Res.*, vol. 66, pp. 3991–4001; December, 1961.) Reduction in cosmic-ray cutoffs at Minneapolis during the main phase of a magnetic storm is attributed to a ring current. The data are used to determine the moment M', and radius R of the ring; surface magnetic disturbances are a function of M'/R^3. It is shown that the ring shrinks during the main phase. Cosmic-ray evidence for a quiet-day ring current is discussed.

523.42:621.396.96 1248
Radar Observation of Venus—I. Maron, G. Luchak, and W. Blitzstein. (*Science*, vol. 134, pp. 1419–1421; November 3, 1961.) Observations were carried out by the BMEW radar system using an 84-ft-diameter antenna. The value of the astronomical unit obtained from these measurements is in satisfactory agreement with values derived by other observatories [*e.g.*, 2567 of 1961 (Thomson, *et al.*)]. See also 104 of January (Malling and Golomb).

523.5:621.396.:6 1249
The Determination of the Incident Flux of Radio-Meteors: Part 2—Sporadic Meteors—T. R. Kaiser. (*Monthly Notices Roy. Astron. Soc.*, vol. 123, no. 3, pp. 265–271; 1961.) The theory relating the radio-echo rate to the incident meteor flux is extended to the case of sporadic meteors. Results for sporacic meteors and several showers are presented. Part 1: 857 of 1961.

523.53 1250
The Identification of Meteor Showers with Application to Southern Hemisphere Results—C. Ellyett, C. S. L. Keay, K. W. Roth, and R. G. T. Bennett. (*Monthly Notices Roy. Astron. Soc.*, vol. 123, pp. 37–50; September, 1961.) Results of recent radar measurements of meteor showers at Christchurch, New Zealand, are combined with previous visual and radar surveys to develop a composite picture of meteor activity. Seven showers are confirmed, appearing in all three surveys; another six to nine are probable, being identified in two.

523.7:621.396.969 1251
Radar Reflections from the Sun at Very High Frequencies—W. G. Abel, J. H. Chisholm, P. L. Fleck, and J. C. James. (*J. Geophys. Res.*, vol. 66, pp. 4303–4307; December, 1961.) Preliminary report of measurements made at 38.25 Mc using a frequency-offset keying technique and transmitted CW power of 500 kw. The results complement those obtained earlier at 26 Mc [2716 of 1960 (Eshleman, *et al.*)].

550.380 1252
Determination of the Nature of the Earth's Distant Magnetic Field—E. R. Harrison. (*Nature*, vol. 193, p. 359; January 27, 1962.) When singly ionized an alkaline-earth element such as Be is a strong resonant scatterer of solar radiation. Released in a gaseous state at a distance of 5–10 earth radii or by atom bomb at about 300 km above the magnetic pole it could be used to map the geomagnetic field in the vicinity of the earth.

550.385 1253
Evidence of Low-Frequency Hydromagnetic Waves in the Exosphere—M. Sugiura. (*J. Geophys. Res.*, vol. 66, pp. 4087–4095; December, 1961.) Damped waves with periods of several minutes are found in the auroral zones. Since their polarization is essentially elliptical, they are interpreted as LF hydromagnetic waves propagated along the magnetic lines of force.

550.385:550.37 1254
Equatorial Electrojet in Ghana.—D. G. Osborne. (*Nature*, vol. 173, pp. 567–568; February 10, 1962.) The variability of the diurnal range of the vertical magnetic-field component observed at Tamale, Ghana, is explained by changes in position and intensity of the electrojet.

550.385.4 1255
Hydromagnetic Interpretation of Sudden Commencements of Magnetic Storms—C. R. Wilson and M. Sugiura. (*J. Geophys. Res.*, vol. 66, pp. 4097–4111; December, 1961.) A model is proposed in which the impact of solar plasma on the geomagnetic field generates a shock wave. The compressional shock wave propagates to the earth as a longitudinal hydromagnetic wave in low latitudes and generates transverse hydromagnetic waves in the exposure, which propagate to high latitudes along the field lines. A reversed impulse at latitudes above 40° is explained in terms of the direction of the magnetic perturbation vector at the top of the ionosphere.

550.385.4:523.165 1256
The Magnetic Field of a Model Radiation Belt, Numerically Computed—S.-I. Akasofu, J. C. Cain, and S. Chapman. (*J. Geophys. Res.*, vol. 66, pp. 4013–4026; December, 1961.) The magnetic field of a model ring-current belt [2946 of 1961 (Akasofu and Chapman)] is calculated numerically. Over the earth's surface the field of the ring current is nearly uniform, although the diamagnetism of the belt produces an insignificant irregularity in the disturbance field in auroral latitudes.

551.507.362.1 1257
Scientific Research Recently Carried Out by means of 'Veronique' Rockets. Experiments on the Physics of the High Atmosphere—É. Vassy. (*Onde élect.*, vol. 41, pp. 778–782; October, 1961.) A report of measurements made in a recent series of tests. The rocket and associated telemetry equipment are described, *ibid.* pp. 771–773 (J. Marchal) and pp. 774–777 (C. Fayard).

551.507.362.2 1258
A Year of Photographic Observations of Artificial Satellites at the Astrophysical Observatory of Asiago—L. Rosino and A. Mammano. (*Ricerca Sci.*, pt. 2A, vol. 1, pp. 23–35; October, 1961.) Results of the first year's observations commencing September 1, 1959 are tabulated.

551.507.362.2 1259
Ionospheric Limitations on Attainable Satellite Potential—D. B. Beard and F. S. Johnson. (*J. Geophys. Res.*, vol. 66, pp. 4113–4122; December, 1961.) Consideration of the potentials attainable by a satellite in the ionosphere when a) continuous streams and b) pulsed streams of charged particles are ejected from it.

551.507.362.2 1260
The Motion of an Artificial Earth Satellite in the Normal Gravitational Field of the Earth—M. D. Kislik. (*Isk. Sput. Zemli*, no. 4, pp. 3–17; 1960.) English trans., *Planet-Space Sci.*, vol. 8, pp. 86–96; November, 1961.) Mathematical treatment of satellite motion neglecting air resistance and gravitational anomalies. Results can be applied to the calculation of satellite orbits at high altitudes.

551.507.362.2 1261
Analytical Approach to the Perturbation Problem for an Artificial Satellite—J. Kovalevsky (*Astronautica Acta*, vol. 7, nos. 5/6, pp. 376–289; 1961. In French.)

551.507.362.2 1262
The Effect of Atmospheric Oblateness on a Satellite Orbit—D. G. King-Hele. (*Astronautica Acta*, vol. 7, nos. 5/6, pp. 390–405; 1961. Discussion.)

551.507.362.2 1263
The Stability of the 24-Hour Satellite—L. Sehnal. (*Astronautica Acta*, vol. 7, nos. 5/6, pp. 445–455; 1961. Discussion.) Perturbations of the orbit by the sun, earth and particularly the moon are investigated using a method of numerical integration.

551.507.362.2 1264
Effects of the Earth's Magnetic Field on the Orbit of a Charged Satellite—I. I. Shapiro and H. M. Jones. (*J. Geophys., Res.*, vol. 66, pp. 4123–4127; December, 1961.) The main effect of the earth's magnetic field on a charged satellite is to cause the node to precess. For the West Ford needles, the precession amounts to about 0.0008°/day.

551.507.3o2.2 1265
The Effects of Atmospheric Refraction on Angles Measured from a Satellite—A. C. Holland. (*J. Geophys., Res.*, vol. 66, pp. 4171–4175; December, 1961.)

551.507.362.2 1266
Electron Temperature Measurements on the Explorer VIII Satellite—G. P. Serbu, R. E. Bourdeau, and J. L. Donley. (*J. Geophys. Res.*, vol. 66, pp. 4313–4315; December, 1961.) The diurnal variation of electron temperature at altitudes of 400–1200 km is obtained from a modified Langmuir probe experiment. Temperatures range between 950° and 1800°K.

551.507.362.2 1267
The Canadian Defence Research Board Topside Sounder Satellite—R. C. Langille and J. C. W. Scott. (*J. Brit. IRE*, vol. 23, pp. 61–68; January, 1962. Discussion.) The satellite is designed to measure the characteristics of the ionosphere above the region of maximum ionization. It will be placed in a circular orbit 625 miles above the earth inclined at 80° and precessing westward. The sounder will cover the frequency range 1.8–11.5 Mc in 10-sec sweeps on command from ground stations. Two telemetry transmitters will operate at frequencies near 136 Mc.

551.510.535 1268
Identification of Sporadic-E from Low-Frequency Sweep Polarization Records—A. J. Ferraro and G. P. Tou. (*Nature*, vol. 193, pp. 461–462; February 3, 1962.) Reversals in the direction of rotation of the polarization ellipse are interpreted using the wave theory of reflection from a thin sharply-bounded layer in the ionosphere.

551.510.535 1269
The Seasonal Anomalies in the F Region—G. A. M. King. (*J. Geophys. Res.*, vol. 66, pp. 4149–4154; December, 1961.) The seasonal variations in noon F2 critical frequency, and in the occurrence of F-layer bifurcation, are ascribed to changes in the electron-loss coefficient. These are related to a seasonal variation in frequency of occurrence of traveling disturbances, and a connection with atmospheric tides is proposed.

551.510.535 1270
Horizontal Diffusion and the Geomagnetic Anomaly in the Equatorial F Region—A. J. Lyon: H. Rishbeth. (*Nature*, vol. 193, pp. 55–56; January 6, 1962.) Equations relating to the diffusion of F-region ionization parallel to the earth's field are stated, and used to discuss low-latitude phenomena. One implication of the analysis is criticized in the adjoining note, which attempts a qualitative description of the role of diffusion in the equatorial F region.

551.510.535:523.164 1271
Determination of Drift Movements of the Ionosphere at High Latitudes from Radio Star Scintillations—L. Harang and K. Malmjord. (*Geofys. Publik (Oslo)*, vol. 23, 12 pp., December, 1961. In English). An apparent reversal in drift direction of the N-S component in three-antenna radio scintillation measurements at Tromsø is discussed. It can be explained by assuming the diffracting medium to consist of elongated "blobs" with the main direction lying along the projection of the geomagnetic field lines as seen from the radio source. See 121 of 1956 (Spencer).

551.510.535:523.745 1272
Solar-Activity Effect and Diurnal Variation in the Upper Atmosphere—W. Priester. (*J. Geophys. Res.*, vol. 66, pp. 4143–4147; December, 1961.) An examination is made of the characteristics of the solar activity variations in upper atmosphere density, and it is suggested that a source of heating from the solar "wind" must be involved, as well as solar ultraviolet heating to explain the observed effects.

551.510.535:523.75 1273
Sudden Increase in the Ionosphere F_2-Region Ionization Associated with Solar Flares—L. Q. Orsini and R. H. Mazzilli. (*Nature*, vol. 193, pp. 462–463; February 3, 1962.) Five cases are reported; in one case the attachment coefficient was estimated from the ensuing decay. The result was somewhat higher than the value indicated by Ratcliffe (*Physics of the Upper Atmosphere*, p. 435; 1960).

551.510.535:550.385.4 1274
Ionospheric Currents Responsiple for Sudden Commencements Observed at the Geomagnetic Equator—T. Ondoh. (*J. Geophys. Res.*, vol. 66, pp. 4155–4161; December, 1961.) The height and strength of the line current which would account for the sc at two equatorial stations is calculated. For 27 storms the height is found to lie between 300 and 1000 km and is independent of the local time of sc. A more realistic sheet-current model is examined and is found to be insensitive to height. An explanation of enhanced sc at the equator is given.

551.510.535:621.391.812.63 1275
Man-Made Heating and Ionization of the Upper Atmosphere—P. A. Clavier. (*J. Appl. Phys.*, vol. 32, p. 2651; December, 1961.) Correction to 2599 of 1961.

551.510.535:621.391.812.63 1276
Doppler Studies of the Ionosphere with Vertical Incidence—K. Davies. (Proc. IRE, vol. 50, pp. 94–95; January, 1962.) A descrip-

tion is given of a method for determining whether observed Doppler shifts are due to changes in height of reflection or to ionization changes in the lower ionosphere.

551.510.535(98/99):621.391.812.63 1277
Polar Ionospheric Spread Echoes and Radio-Frequency Properties of Ice Shelves—S. Evans. (*J. Geophys. Res.*, vol. 66, pp. 4137–4141; December, 1961.) Records from three stations in the Antarctic and one drifting station from an ionosonde antenna is reflected from sea water under the ice. An interference pattern is established from which it is possible to determine a) the thickness and dielectric constant of the ice, and b) the direction from which ionospheric spread echoes arise.

551.510.535(98):621.391.812.631 1278
A Study of the Enhanced Ionization Produced by Solar Protons during a Polar-Cap Absorption Event—G. C. Reid. (*J. Geophys. Res.*, vol. 66, pp. 4071–4085; December, 1961.) The electron-density/height profiles produced by solar protons are examined theoretically. The cosmic-noise absorption expected from these profiles are compared with experimental data. Particular attention is paid to the sunrise and sunset periods. The presence of O_2^- alone is insufficient to account for the observations at these times.

551.510.535(98):621.391.812.631 1279
Polar-Cap Absorption following the Solar Flare of July 16, 1959—S. Ziauddin. (*Canad. J. Phys.*, vol. 39, pp. 1882–1887; December, 1961.) The absorption records at Saskatoon and Ottawa during the polar-cap absorption event showed short-term recoveries of the cosmic noise level which were associated with auroral disturbances. It is suggested that these recoveries were due to a magnetic screening of the particles causing the polar-cap absorption events.

551.510.535(98):621.391.812.631 1280
Minor P.C.A. Events during March 1958—G. F. Rourke. (*J. Geophys. Res.*, vol. 66, pp. 4316–4318; December, 1961.) Two polar-cap absorption events are described in detail.

551.510.535(99) 1281
Interrelations among the Upper Atmosphere Disturbance Phenomena in the Auroral Zone—T. Oguti and T. Nagata. (*Rep. Ionos. Space Res. Japan*, vol. 15, pp. 31–50; March, 1961.) An analysis of data from Syowa Station, Antarctica, reveals a numerical relation between the intensity of the λ 5577 line, the maximum electron density of E_s ionization, and the magnitude of the horizontal disturbance vector.

551.510.535"1961" 1282
Ionosphere Review: 1961—T. W. Bennington. (*Wireless World*, vol. 68, pp. 110–111; March, 1962.) A comment on ionospheric conditions including a note on probable sunspot activity up to the end of 1962 with specia reference to effects on long-distance communication.

551.593.5 1283
Lunar Time Variation of Oxygen Green Line in the Night Airglow—T. Tohmatsu, E. Kaneda, and T. Nagata. (*Rep. Ionos. Space Res. Japan*, vol. 15, pp. 90–93; March, 1961.) It is suggested that the lunar time variation in the intensity of the λ 5577 line is due to the tidal influence on the density of oxygen atoms near the 100-km level.

551.594.5 1284
Collision Processes in the Aurorae and Ionization in the Auroral Zone—K. Takayanagi and T. Yonezawa. (*Rep. Ionos. Space Res. Japan*, vol. 15, pp. 51–69; March, 1961.) A review of present knowledge which includes the stopping power of air, the charge changing in proton beams and ionization processes.

551.594.5:621.391.812.63 1285
Rocket Measurements of Auroral Radio Absorption—W. J. Heikkila and S. R. Penstone. (*Canad. J. Phys.*, vol. 39, pp. 1875–1881; December, 1961.) The variation of ionospheric absorption with height was studied by measuring the signal strength of a 22-Mc transmission from the ground. The results from a flight on October 28, 1960, indicated that most of the absorption occurred between 65 km and 90 km, the peak being in the 70–75-km region.

551.594.5:621.391.812.63 1286
Direct Measurement of Charged Particles associated with Auroral-Zone Radio Absorption—I. B. McDiarmid, D. C. Rose, and E. Budzinski. (*Canad. J. Phys.*, vol. 39, pp. 1888–1900; December, 1961.) Rocket observations of electrons with energy >30 kev and protons with energy >500 kev are described. During ascent the electron flux showed large and rapid fluctuations which are consistent with a columnar structure, while the proton intensity was relatively steady. An estimate is made of the integral electron energy spectrum and the angular distribution of both electrons and protons are examined.

551.594.6 1287
Whistler Dispersion for a Model of the Ionic Distribution in the Exosphere—T. N. L. Patterson. (*Planet-Space Sci.*, vol. 8, pp. 71–76; November, 1961.) An investigation into the dispersion of whistlers for a range of exospheric temperature, latitude and ion content.

LOCATION AND AIDS TO NAVIGATION

621.396.933.2:629.19 1288
Redesigning Project Mercury Beacons—J. G. Richter. (*Electronics*, vol. 35, pp. 50–52; January 19, 1962.) The encoded beacon transmission provides a visual display which gives identification and directional information.

621.396.96 1289
Automatic Extraction of Radar Information in Numerical Form—L. Gérardin and R. Barbier. (*Onde élect.*, vol. 41, pp. 783–794; October, 1961.) Practical limitations of a radar system are considered and a method of normalizing video information into binary code is suggested. By appropriate treatment of this code in a storage system a receiver can be designed with sensitivity only 1.8 db below ideal. An experimental receiver of this type is described.

621.396.:96:551.5 1290
Radar Angels in the Lower Troposphere—D. R. Hay and W. M. Reid. (*Canad. J. Phys.*, vol. 40, pp. 128–138; January, 1962.) Observations were made for one year in 1960 at 6800 Mc at London, Canada. Transitory angels appear to arise through eddy mixing in the lower troposphere and persistent angels are associated in some way with a high concentration of moisture at ground level.

621.396.96:621.391.812.621 1291
A 'Layered' Exponential Modal of Radar Refractivity—Martin and Waldron. (See 1390.)

621.396.969 1292
Air and Space Navigation System uses Cross-Correlation Detection Techniques—R. J. Miller. (*Electronics*, vol. 34, pp. 55–59; December 15, 1961.) Energy scattered from the earth's surface is received by spaced antennas on the vehicle. Cross correlation between the detected outputs gives the vehicle, surface speed and drift angle.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7 1293
Vacuum Measurements by means of Alternating Gas Discharges—E. H. Hirsch. (*Rev. Sci. Instr.*, vol. 32, pp. 1373–1377; December, 1961.) The pressure of a gas is measured as a function of the frequency of a relaxation oscillator, the nonlinear element of which is a glow discharge between two electrodes in the gas. A stability of 1 per cent is achieved over a range of 10^{-5} to 6 mm Hg.

535.215:546.24 1294
Photoconductivity in Single-Crystal Tellurium—D. F. Edwards, C. D. Butter, and L. D. McGlauchlin. (*Solid-State Electronics*, vol. 3, pp. 24–28; July, 1961.) Measurements on Te crystals grown from the vapor phase and from the melt demonstrate the possibility of constructing Te photocells whose ultimate detectivity is limited by background radiation.

535.215:546.47'221 1295
The Influence of an Electric Field on the Absorption Edge of ZnS—S. Damašková and K. Pátek. (*Z. Phys.*, vol. 164, pp. 428–430; September 4, 1961.) The absorption-edge shift observed in CdS by Böer (1637 of 1960) is investigated in ZnS single crystals.

535.215:546.48'241 1296
Photoelectric Emission from Cadmium Telluride—J. J. Scheer and J. van Laar. (*Philips Res. Repts.* vol. 16, pp. 323–328; August, 1961.) The most reliable value for the work function is obtained from measurements on freshly cleaved particles.

535.37:546.48'221 1297
Luminescence of CdS Single Crystals—H. Friedrich. (*Z. Naturforsch.*, vol. 16a, pp. 1106–1107; October, 1961.) Report on investigations of the enhancement of blue luminescence at low temperature.

535.37:546.48'221 1298
Luminescence accompanied by Electrolysis in CdS Single Crystals—E. Maruyama. (*J. Phys. Soc. Japan*, vol. 16, pp. 2341–2342; November, 1961.) Surface luminescence having a broad band around 600 mμ with a spectral distribution dependent on the kind of negative ions present is described.

535.376 1299
Effects of Interaction among Particles in Electroluminescent Layers—A. T. Halpin and P. Goldberg. (*J. Electrochem. Soc.*, vol. 108, pp. 1028–1034; November, 1961.) The optical and electrical characteristics of electroluminescent layers are discussed in terms of experimentally determined properties of individual phosphor grains modified by interactions with neighboring particles.

535.376 1300
Microsecond Response of Electroluminescent Cells—J. E. Johnson. (*J. Electrochem. Soc.*, vol. 108, pp. 852–855; September, 1961.) Measurements of response show a rise time of about 1 μs and a decay time of 7 μs.

535.376.08 1301
Measuring Phosphor Resolution—G. A. Leavitt. (PROC. IRE, vol. 50, pp. 95–96; January, 1962.) A method of measuring the resolution of phosphor screens using an electron gun and a fine metallic mesh is described.

537.226:546.824–31 1302
Static Dielectric Constant of Rutile (TiO_2), 1.6–1060°K—R. A. Parker. (*Phys. Rev.*, vol. 124, pp. 1719–1722; December 15, 1961.) In

this temperature range no ferroelectric or antiferroelectric transitions occur. The ionic polarizability and its temperature variation are determined.

537.227 1303
Growth and Electrical Properties of Ferroelectric Glycine Sulphate Single Crystals—H. Toyoda, Y. Tanaka, W. Shiokawa. (*Rev. Elec. Comm. Lab. Japan*, vol. 9, pp. 485–496; July/August, 1961.) An experimental investigation of the effects of crystal imperfections on crystal growth, dislocation lines, electrical conductivity, and dielectric constant.

537.227 1304
Dielectric Properties of Ferroelectric $NaNO_2$—S. Sawada, S. Nomura and Y. Asao. (*J. Phys. Soc. Japan*, vol. 16, pp. 2207–2212; November, 1961.) The temperature dependence of the D/E hysteresis loops, the pyroelectric current and the dielectric constant along the ferroelectric b axis, ϵ_b, were examined in $NaNO_2$ crystals. ϵ_b deviated markedly from a Curie-Weiss law at the Curie temperature.

537.227:537.311.33 1305
Possible Explanation of Positive Temperature Coefficient in Resistivity of Semiconducting Ferroelectrics—W. T. Peria, W. R. Bratschun, and R. D. Fenity. (*J. Amer. Ceram. Soc.*, vol. 44, pp. 249–250; May, 1961.) A model is suggested in which the dc resistance is mainly developed at the intercrystalline boundaries. If the crystallites are improperly sintered, the contacts will be pressure-sensitive and nonohmic, and an increase in temperature will produce a change in contact resistance.

537.227:546.431'824–31 1306
High-Pressure Investigations on Barium Titanate Ceramics—M. Richard. (*Ann. Phys.* (*Lpz.*), vol. 8, pp. 333–341; September 4, 1961.) Measurements of the effect of hydrostatic pressure up to 4000 kiloponds/cm² on the dielectric constant and loss angle of $BaTiO_3$ solid solutions with $PbTiO_3$ and $SrTiO_3$.

537.227:546.431'824–31 1307
Motion of c Domain Centres in $BaTiO_3$—G. L. Link. (*J. Appl. Phys.*, vol. 32, pp. 2566–2573; December, 1961.) On application of a biased alternating field to a crystal containing an a domain, a large number of small "dots" are observed which move in straight lines. These are shown to be small c domains and their motion can be accounted for by the electric field perturbation caused by the a domain.

537.227:546.431'824–31:537.311.33 1308
Barium Titanate as a Barrier-Layer Semiconductor—W. Heywang. (*Solid-State Electronics*, vol. 3, pp. 51–58; July, 1961. In German.) Experimental results are reported and a model is proposed which accounts quantitatively for the abnormal increase with temperature in the resistivity of suitably doped $BaTiO_3$ in a limited range immediately above the Curie point.

537.228 1309
Piezoelectric Materials—C. S. Brown, R. C. Kell, R. Taylor, and L. A. Thomas. (*Proc. IEE*, pt. B, vol. 109, pp. 99–114; January, 1962.) The basic properties of a large range of piezoelectric materials are tabulated and discussed. 82 references.

537.311.33 1310
Macroscopic Physics of Surface Recombination in Semiconductors—A. C. Sim. (*J. Electronics and Control*, vol. 10, pp. 117–126; February, 1961.) The surface condition in which rectifying effects are negligible can only be described by a surface recombination velocity when this is small compared with the diffusion velocity. A model is analyzed in which the excess-charge-carrier lifetime varies with position; the apparent recombination velocity is shown to depend markedly on experimental conditions when the diffusion length is short.

537.311.33 1311
Diffusion of Charged Particles into a Semiconductor under Consideration of the Built-In Field—K. Lehovec and A. Slobodskoy. (*Solid-State Electronics*, vol. 3, pp. 45–50; July, 1961.) The distribution of charged impurities in a semiconductor is calculated for the case of impurities diffusing from the surface into an infinite body, taking account of the electric field arising from the diffusing impurities. The impurity distribution and true surface concentration are plotted.

537.311.33 1312
Donor States and Deformation around Impurity Atoms in Semiconductors—S. Shinohara (*Nuovo Cim.*, vol. 22, pp. 18–30; October 1, 1961. In English) The change of ionization energy of the donor state has been estimated semiquantitatively, assuming that impurity ions produce only point lattice defects. Results suggest that the effective mass equation becomes inadequate in the vicinity of impurity atoms.

537.311.33 1313
Improved Representation of Calculated Surface Mobilities in Semiconductors: Part 1—Minority Carriers—N. B. Grover, Y. Goldstein, and A. Many. (*J. Appl. Phys.*, vol. 32, pp. 2538–2539; December, 1961.) Calculated values are given in a convenient form over the range of practical interest which extends from depletion layers where minority-carrier concentrations are negligible to the strongest inversion layers normally attainable.

537.311.33 1314
Improved Representation of Calculated Surface Mobilities in Semiconductors: Part 2—Majority Carriers—Y. Goldstein, N. B. Grover, A. Many, and R. F. Greene. (*J. Appl. Phys.*, vol. 32, pp. 2540–2541; December, 1961.) The surface mobility is expressed as a function of the potential barrier by a single family of curves over the entire range of interest of surface potential, material resistivity and temperature.

537.311.33:535.215 1315
Theory for the Photoemission from a Space-Charge Region of a Semiconductor—D. Redfield. (*Phys. Rev.*, vol. 124, pp. 1809–1812; December 15, 1961.) The relative importance of volume and surface photoeffects is considered. Conclusions about the threshold region are made and some anomalous effects explained.

537.311.33:537.32.08 1316
Apparatus for the Rapid Scanning of the Seebeck Coefficient of Semiconductors—L. E. J. Cowles and L. A. Dauncey. (*J. Sci. Instr.*, vol. 39, pp. 16–18; January, 1962.) The Seebeck coefficient of the specimen heated by a probe is determined from a direct-reading potentiometer. A large number of points can be quickly plotted to show material inhomogeneity.

537.311.33:537.322 1317
Thermoelectric Application of Semiconductors—P. Gerthsen. (*Z. angew. Phys.*, vol. 13, pp. 435–444; September, 1961.) Review of underlying principles and various types of application. 57 references.

537.311.33:538.614 1318
The Theory of the Faraday Effect in Anisotropic Semiconductors—B. Donovan and J. Webster. (*Proc. Phys., Soc.* (*London*) *A*, vol. 79, pp. 46–57; January, 1962.) A theory is developed for the Faraday rotation and ellipticity in terms of the HF magnetoconductivity tensor.

537.311.33:546.23:537.226 1319
Dielectric Relaxation Phenomena in High-Purity Selenium—F. Eckhart and W. Ludwig. (*Z. Naturforsch.*, vol. 16a, pp. 1107–1108; October, 1961.) See also 4179 of 1961 (Ludwig and Eckhart).

537.311.33:[546.28+546.289 1320
High-Field Conductivity in Germanium and Silicon at Microwave Frequencies—J. Zucker, V. J. Fowler, and E. M. Conwell. (*J. Appl. Phys.*, vol. 32, pp. 2606–2611; December, 1961.) Measurements were made of the effect on the conductivity of Ge and Si samples of 2.85-Gc electric fields up to peak value of 10,000 v/cm. The instantaneous conductivity was calculated and found to agree with the dc conductivity.

537.311.33:[546.28+546.289 1321
Study of Germanium by Transparency in Infrared Light; Double Refraction of Silicon and Germanium—C. Grandjean. (*Philips Res. Repts.*, vol. 16, pp. 343–355; August, 1961.)

537.311.33:546.28 1322
Effects of Heat Treatment on Diffused Silicon Material—A. L. MacDonald and W. J. Heinecke. (*Semiconductor Prod.*, vol. 4, pp. 19–23; September, 1961.) The effects of cooling, quenching and annealing several n-type Si single crystals are described. Their bearing on the selection or preparation of material for a particular device is briefly discussed.

537.311.33:546.28 1323
Single-Crystal Silicon Overgrowths—A. Mark. (*J. Electrochem. Soc.*, vol. 108, pp. 880–885; September, 1961.)

537.311.33:546.28 1324
Voltage Dependence of Microplasma Density in p-n Junctions in Silicon—A. Goetzberger and C. Stephens. (*J. Appl. Phys.*, vol. 32, pp. 2646–2650; December, 1961.) The voltage distribution of breakdown spots was measured. A particular junction in Si showed two kinds of microplasma, one characterized by light emission and low breakdown voltage and the other by less light emission and higher breakdown voltage.

537.311.33:546.28:621.3.032.27 1325
Electrical Characteristics of a Reduced-Area, Rhodium-Plated Silicon End Contact—M. Green, I. N. Greenberg, J. Banzhaf, A. Sass, H. S. White, and R. V. McKnight. (*Solid-State Electronics*, vol. 3, pp. 1–10; July, 1961.) An explanation is given of the rectifying characteristic observed in a high-purity p-type single crystal of Si with Rh-plated ends after grinding a reduced-area contact at one end. Voltage-profile and resistivity measurements were made in the range $-196°$ to $+116°C$.

537.311.33:546.281'26 1326
Grown p-n Junctions in Silicon Carbide: Part 2—C. A. A. J. Greebe and W. F. Knippenberg. (*Philips Res. Repts.*, vol. 16, pp. 389–398; August, 1961.) Inhomogeneities in the current density distribution over the junction area were analyzed. The spatial distribution of the p-n luminescence for photon energies greater than the band-gap tended to fit the van Roosbroeck-Shockley theory. Part 1: 1563 of 1961.

537.311.33:546.289 1327
Thermal Conversion of Germanium—W. Albers. (*J. Electronics and Control.*, vol. 10, pp. 197–206; March, 1961.) A survey is given

of the thermal conversion phenomenon. A method is described that is generally applicable for eliminating thermal conversion after heat treatment of Ge.

537.311.33:546.289 1328
Recombination of Electrons and Donors in *n*-Type Germanium—G. Ascarelli and S. Rodriguez. (*Phys. Rev.*, vol. 124, pp. 1321–1328; December 1, 1961.) Capture of the electron in a donor-excited state followed by successive phonon emission to the ground state gives cross sections of the right order. Simplifying assumptions limit the quantitative accuracy of the model.

537.311.33:546.289 1329
Low-Field Breakdown in *n*-Type Germanium—G. Ascarelli. (*Nuovo Cim.*, vol. 22, pp. 251–265; October 16, 1961. In English). Measurements of the time necessary to produce low-field breakdown in *n*-type Ge have been made as a function of the applied electric field. This time interval is proportional to E^{-2}. An explanation of these results and those obtained from dc measurements is given.

537.311.33:546.289 1330
Field-Retarded Diffusion of Antimony in Germanium—C. Fa and R. Zuleeg. (*Solid-State Electronics*, vol. 3, pp. 18–23; July, 1961.) The influence of the field produced by Ga impurity ions on diffusion properties of Sb in Ge are examined theoretically and experimentally for the temperature range 700°–900°C.

537.311.33:546.289 1331
Current/Voltage Characteristics of Plastically Deformed Germanium *p-n* Junctions—O. Ryuzan. (*J. Phys. Soc. Japan*, vol. 16, pp. 2177–2187; November, 1961.) Grown-junction diode bars were used to investigate the influence of dislocations introduced by plastic deformation: a *p-n-p-n* structure was found to have been produced in the original *p-n* junction region.

537.311.33:546.289 1332
Activation Energy of Acceptors Introduced into Germanium by Plastic Twisting—O. Ryuzan. (*J. Phys. Soc. Japan*, vol. 16, pp. 2339–2340; November, 1961.) The Hall coefficient, resistivity and electron and hole mobilities were determined for a twisted specimen as a function of $1/T$. Hole concentration plotted against $1/T$ gave an activation energy of 0.06 ev.

537.311.33:546.289:538.569.4 1333
Cyclotron Resonance of Hot Electrons in Germanium—H. Kawamura, Y. Hayashi, and M. Fukai. (*J. Phys. Soc. Japan*, vol. 16, pp. 2352–2353; November, 1961.) Experimental resonance curves are shown together with data on line width and current densities.

537.311.33:546.289:538.614 1334
The Infrared Faraday Effect in Germanium—A. K. Walton and T. S. Moss. (*Proc. Phys. Soc. (London) A*, vol. 78, pp. 1393–1407; December 15, 1961.) In *n*-type Ge, the results of Faraday-effect measurements are used to evaluate the Hall scattering constant. In intrinsic Ge, near the absorption edge a reversal of sign is observed. In *p*-type Ge, the rotation is a complex function of λ and is interpreted as being due to light and heavy holes and inter-valence-band transitions.

537.311.33:546.289:539.12.04 1335
Radiation-Induced Recombination and Trapping Centres in Germanium: Part 1—The Nature of the Recombination Process—O. L. Curtis, Jr. and J. H. Crawford, Jr. (*Phys. Rev.*, vol. 124, pp. 1731–1740; December 15, 1961.) Measurements indicate that previous analyses of the recombination process are incorrect. A new model is presented. Trapping levels in Sb- and As-doped Ge are investigated.

537.311.33:546.289:548.0 1336
Germanium Dendrite Studies—J. W. Faust, Jr. and H. F. John. (*J. Electrochem. Soc.*, vol. 108, pp. 855–868; September, 1961.) A series of three papers covering twin structures and the seeding mechanisms, lateral growth processes, and dislocations.

537.311.33:546.289:548.5 1337
An Apparatus for the Manufacture of Semiconductor Single Crystals by the Method of Vertical Pulling—V. Andresciani and D. Sette. (*Alta Frequenza*, vol. 30, pp. 575–582; August, 1961.) Description of an improved apparatus for crystal pulling by the Czochralski method. Details are given of high-purity Ge crystals obtained.

537.311.33:546.3–1'87'86 1338
Concentration Dependence of Electrical Properties of Bismuth-Antimony Alloys—S. Tanuma. (*J. Phys. Soc. Japan*, vol. 16, p. 2349; November, 1961.) From measured values of resistivity, Hall coefficient and magnetoresistance for various Sb concentrations, the concentration and mobilities of electrons and holes have been calculated.

537.311.33:546.3–1'87'86:537.323 1339
Thermoelectric Power of Bismuth-Antimony Alloys—S. Tanuma. (*J. Phys. Soc. Japan*, vol. 16, pp. 2354–2355; November, 1961.)

537.311.33:546.47'86 1340
Electric Transport Parameters of ZnSb at Low Temperatures—O. V. Emeljanenko, E. Justi, and G. Schneider. (*Z. Naturforsch.*, vol. 16a, pp. 1108–1110; October, 1961.) Report on measurements of thermo-EMF, electrical conductivity, Hall, Nernst-Ettingshausen and magnetoresistance effects in the temperature range 4.2°–300°K.

537.311.33:546.48'86 1341
The Semiconducting Properties of CdSb—F. Ermanis and E. Miller. (*J. Electrochem. Soc.*, vol. 108, pp. 1048–1052; November, 1961.) An investigation to determine the crystallographic directions corresponding to the anisotropic variation of properties in CdSb, and the electronic and optical properties in one crystal direction as a function of temperature.

537.311.33:546.571'221 1342
On the Theory of Mixed Conduction with Special Reference to the Conduction in Silver Sulphide Group Semiconductors—I. Yokota. (*J. Phys. Soc. Japan*, vol. 16, pp. 2213–2223; November, 1961.) A diffusion equation is obtained which can readily be integrated under given boundary conditions. General expressions for potential distributions are derived whose theoretical time variations show satisfactory agreement with experiment.

537.311.33:546.681'19 1343
The Dember and Photoelectromagnetic Effects in Semi-insulating Gallium Arsenide—C. M. Hurd. (*Proc. Phys. Soc. (London) A*, vol. 79, pp. 42–45; January 1, 1962.) Measurements are described which cover the temperature range 140°–300°K.

537.311.33:546.682'19 1344
Investigations on the Healing Process of Frenkel Defects in Indium Arsenide—R. Bäuerlein. (*Z. Naturforsch.*, vol. 16a, pp. 1002–1008; October, 1961.) Observation of the annealing of defects caused by electron bombardment at 400 kev, in the temperature range 77°–500°K.

537.311.33:[546.682'241+546.681'241 1345
Some Properties of In_2Te_3 and Ga_2Te_3—J. C. Woolley and B. R. Pamplin. (*J. Electrochem. Soc.*, vol. 108, pp. 874–879; September, 1961.) A summary of measurements of thermal expansion, conductivity and Hall effect.

537.311.33:546.682'86 1346
Properties of Injected Plasmas in Indium Antimonide—B. Ancker-Johnson, R. W. Cohen, and M. Glicksman. (*Phys. Rev.*, vol. 124, pp. 1745–1753; December 15, 1961.) Injection times, pinch effect, I/V curves near breakdown and Hall voltages have been determined. The effects of magnetic field and current on plasma oscillations are described.

537.311.33:546.824–31 1347
Electrical Resistivity and Defect Energy Levels in Reduced Titanium Dioxide at Low Temperatures—R. R. Hasiguti, K. Minami and H. Yonemitsu. (*J. Phys. Soc. Japan*, vol. 16, pp. 2223–2226; November, 1961.

537.311.33:546.873'241 1348
Preparation of Rectangular Prismatic Specimens of Bismuth Telluride and Attachment of Fine Potential Leads—P. T. Bailey. (*Rev. Sci. Instr.*, vol. 32, p. 1416; December, 1961.)

537.311.33:621.317.3 1349
A Method for the Measurement of Short Minority-Carrier Diffusion Lengths in Semiconductors—A. M. Goodman. (*J. Appl. Phys.*, vol. 32, pp. 2550–2552; December, 1961.) The variation of surface photovoltage is measured as a function of optical absorption coefficient. Experimental values are given for *n*- and *p*-type GaAs.

537.312.62 1350
Anomalous Resistive Transitions and New Phenomena in Hard Superconductors—M. A. R. LeBlanc. (*Phys. Rev.*, vol. 124, pp. 1423–1425; December 1, 1961.) An investigation of critical-field/critical-current curves shows the possibility of "conditioning" the specimen to tolerate ever higher currents, up to a maximum, in a superconducting state.

538.221 1351
Properties of Single-Domain Particles of Cobalt-Nickel—R. B. Falk and G. D. Hooper. (*J. Appl. Phys.*, vol. 32, pp. 2536–2538; December, 1961.)

538.221:539.23 1352
Rigorous Calculation of the Nucleation Field in a Ferromagnetic Film or Plate—W. F. Brown, Jr. (*Phys. Rev.*, vol. 124, pp. 1348–1353; December 1, 1961.) Calculations are shown for an electric field applied along the faces of a film and the direction of easy magnetization perpendicular to this. Results are compared with experiment.

538.221:539.23 1353
Observations of Uniaxial Anisotropy in Ferromagnetic Thin Films by means of Bitter Technique—Y. Odani and Y. Gomi. (*Rev. Elect. Comm. Lab., Japan*, vol. 9, pp. 408–420; July/August, 1961.)

538.221:539.23 1354
Stress and Magnetic Anisotropy in Thin Permalloy Films—M. Prutton. (*Nature*, vol. 173, pp. 565–566; February 10, 1962.) Results of experiments on a range of Ni-Fe films.

538.221:621.318.134 1355
Single-Crystal Ferrite Research—K. Hoselitz. (*Brit. Commun. Electronics*, vol. 9, pp. 23–

27; January, 1962.) A review of ferrite production and measurement techniques.

538.221:621.318.134 1356
The Effect of a D.C. Magnetic Field on the U.H.F. Permeability and Losses of some Hexagonal Magnetic Compounds—R. L. Harvey, I. Gordon, and R. A. Braden. (*RCA Rev.*, vol. 22, pp. 648–657; December, 1961.) Hexagonal ferrite materials are described for use as tuning elements at frequencies between 250 and 1750 Mc. They are found to be superior to cubic ferrites in this range. See 2687 of 1959 (Stuijts and Wijn).

538.221:621.318.134 1357
Microwave Properties of Polycrystalline Hybrid Garnets—G. R. Harrison and L. R. Hodges, Jr. (*J. Amer. Ceram. Soc.*, vol. 44, pp. 214–220; May, 1961.) Solid solutions of Y-Fe garnet with Gd-Fe, Sm-Fe, Y-Al, Y-Ga and Y-Cr garnets were examined. Measurements of Curie temperature, line width, saturation magnetization and effective g-factor were made.

538.221:621.318.134 1358
Dispersion of the Complex Permeability in Lithium Ferrite—F. Voigt. (*Ann. Phys. (Lpz.)*, vol. 8, pp. 278–279; September 4, 1961.) Previous measurements of transverse complex susceptibility (1288 of 1959) are discussed in the light of the recent determination of the crystal anisotropy constant.

538.221:621.318.134 1359
Production of Magnetic Anisotropy in Ferrites by Thermomechanical Treatment—R. Straubel. (*Ann. Phys. (Lpz.)*, vol. 8, pp. 375–381; September 4, 1961.) Investigation of the effect of mechanical pressure on Ni ferrite rods during sintering.

538.221:621.318.134:538.569.4 1360
Ferrimagnetic Resonance in Rare-Earth-Doped Yttrium Iron Garnet: Part 2—Terbium Substitution—J. F. Dillon, Jr. and L. R. Walker. (*Phys. Rev.*, vol. 124, pp. 1401–1413; December 1, 1961.) The variation of the resonance field with applied field direction, temperature and frequency is given. Calculations are made with assumed crystal fields and show qualitative agreement only. Part 1: 989 of 1961 (Dillon and Nielsen).

538.221:621.318.134:621.372.85 1361
Ferrites at Microwaves—R. McLean and F. M. Aitken. (*Electronic Tech.*, vol. 39, pp. 2–9 and pp. 70–76; January and February, 1962.) A detailed review of the theory and applications of ferrites in microwave circuits with reference to design problems and choice of material.

538.222:538.569.4 1362
Spin-Lattice Relaxation of Chromium Ions in Ruby—J. C. Gill. (*Proc. Phys. Soc. (London) A*, vol. 79, pp. 58–68; January, 1962.)

538.222:538.569.4:535.61–2 1363
Irradiation Control of Oxidation State in Fluorite Crystals containing Samarium—J. Konitzer, J. Longo, R. Jarka and H. N. Hersh. (*Nature*, vol. 193, pp. 157–158; January 13, 1962.) X-ray irradiation of a fluorate crystal containing Sm is shown to decrease the concentration of Sm^{3+} and increase that of Sm^{2+} by a factor of two after 30 min exposure. The crystal subsequently showed more efficient optical maser characteristics.

548.5 1364
Constitutional Supercooling during Crystal Growth from Stirred Melts: Part 1—Theoretical—D. T. J. Hurle. (*Solid-State Electronics*, vol. 3, pp. 37–44; July, 1961.) The theory of constitutional supercooling is applied to the case of crystal growth from a stirred melt. Expressions, applicable to crystal growth using the Czochralski technique, are derived which predict the onset of constitutional supercooling and the magnitude of the supercooling when it exists.

548.5:621.365.5 1365
The Use of R.F. Heating in Growing Crystals by the Czochralski Technique—W. A. Emerson. (*Semiconductor Prod.*, vol. 4, pp. 25–31; October, 1961.)

MATHEMATICS

517.43 1366
Mikusinski Operators—P. Vielhauer. (*Nachrtech.*, vol. 11, pp. 358–361; August, 1961.) Outline of an operational calculus with advantages over the Laplace transform method in calculations on electrical switching processes. See also 1800 of 1956 (Doležal and Kurzweil).

MEASUREMENTS AND TEST GEAR

529.786+621.3.018.41](083.74) 1367
The International Comparison of Atomic Standards of Time and Frequency—L. Essen and J. M. Steele. (*Proc. IEE*, pt. B, vol. 109, pp. 41–47; January, 1962.) Some details are given of the atomic standards and methods of measurement used at the National Physical Laboratory and the results obtained from 1958 to 1960 for seven standards are tabulated. The use of the VLF transmissions from GBR (16 kc) and NBA (18 kc) enable day-to-day comparisons to be made to an accuracy within ± 2 parts in 10^{10}. Results indicate that there are at present differences between the atomic standards of ± 2 parts in 10^{10}.

621.3.018.41(083.74) 1368
The Comparison of Highly Stable Frequency Standards—E. G. Hope. (*Proc. IEE*, pt. B, vol. 109, pp. 48–52; January, 1962.) The methods used at the National Physical Laboratory are described and reference is made to a proposed method for controlling a 5-Mc quartz oscillator by means of Cs resonance.

621.3.018.41(083.74):621.375.9:538.569.4 1369
$N^{15}H_3$ Double-Beam Maser as a Primary Frequency Standard—J. De Prins, C. Menoud, and P. Kartaschoff. (*Rev. Sci. Instr.*, vol. 32, pp. 1267–1268; November, 1961.) The design is based on the 3,3 line of $N^{15}H_3$ using a magnetic-field criterion for frequency measurements. Comparison of two masers with a quartz primary standard showed both were equal in frequency within the experimental error of $\pm 5 \times 10^{-11}$.

621.317:621.314.22 1370
Measuring Toroidal Transformer Ratios—T. R. Foord and R. C. Langlands. (*Electronic Tech.*, vol. 39, pp. 59–66; February, 1962.) A permutation method is described by which nominally integral voltage ratios can be measured to within one part in 10^6 at AF.

621.317.337.029.6 1371
Measuring Q in the Million Range at Millimetre Wavelengths—F. Parisi. (*Alta Frequenza*, vol. 30, pp. 523–527; July, 1961.) English version of 3504 of 1961.

621.317.42.029.64 1372
Microwave Magnetic-Field Measurements by a Modulated Scattering Technique—B. J. Strait and D. K. Cheng. (*Proc. IEE*, pt. B, vol. 109, pp. 33–40; January, 1962.) An experimental technique is described and extensive data are given for amplitude and phase distributions of both electric and magnetic fields over a circular aperture irradiated by a plane wave.

621.317.44:621.374.3 1373
Magnetic Measurements on Iron Cores with Pulse Drive—G. Käs. (*Elektron. Rundschau*, vol. 15, pp. 517–520; November, 1961.) Description of test procedure for tape-wound cores and measuring equipment including a pulse generator for power pulses of continuously variable duration and repetition frequency.

621.317.441 1374
Note on Search Coil Errors in the Measurement of Axial Magnetic Fields—A. Pearson. (*J. Sci. Instr.*, vol. 39, pp. 8–10; January, 1962.) The error due to a search coil depends upon the even-order derivatives of the actual flux distribution. By careful coil design, the error can in some cases be eliminated.

621.317.444 1375
Frequency-Shift Magnetometer—R. M. Rogers and R. H. Kantor. (*Rev. Sci. Instr.*, vol. 32, pp. 1230–1234; November, 1961.) The saturation magnetization and anisotropy constants of a ferrite or garnet are determined by placing the sample in a dc magnetic field and using it as the core of an RF oscillator coil. As the magnetic field is changed, the frequency of the RF oscillator changes and becomes a measure of the magnetization.

621.317.444:550.385 1376
A Metastable Helium Magnetometer for Observing Small Geomagnetic Fluctuations—A. R. Keyser, J. A. Rice, and L. D. Schearer. (*J. Geophys. Res.*, vol. 66, pp. 4163–4169; December, 1961.) The instrument uses the principle of optical pumping and has a sensitivity of order $10^{-2}\gamma$. Recordings taken during a magnetic storm are shown.

621.317.74:621.372.826 1377
A New Measuring Circuit for Dielectric Surface-Wave Transmission Lines—G. Schulten. (*Nachrtech. Z.*, vol. 14, pp. 445–448; September, 1961.) A device for measuring the reflection coefficient on dielectric lines and image lines and at very short wavelengths is described. It is based on the combination of the standing wave and reflectometer principles (1069 of 1959).

621.317.794 1378
A New Precision Low-Level Bolometer Bridge—W. C. Reisener and D. L. Birx. (PROC. IRE, vol. 50, pp. 39–42; January, 1962.) An ambient-temperature RF sensitivity of 3×10^{-10}w is obtained.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

535.376–52:621.382.32 1379
On the Control of Electroluminescent Cells by Unipolar Transistors—T. N. Chin. (*J. Electronics and Control*, vol. 10, pp. 293–306; April, 1961.) By varying the channel conductance, the supply voltage can be shifted from the unipolar transistor to the electroluminescent cell and vice versa. An approach to the design of a control element is given with an example.

612–08:535.61–2:621.375.9 1380
Physiological Implications of Laser Beams—L. R. Solon, R. Aronson and G. Gould. (*Science*, vol. 134, pp. 1506–1508; November 10, 1961.) The hazard associated with laser

beams, and the application of the beam as biological and clinical tool are discussed.

621.383.5:621.374.32 1381
Photoconductive Matrix Simplifies Counter Display—B. H. Harrison. (*Electronics*, vol. 34, pp. 28–30; December 22, 1961.) The photoconductor/neon-bulb matrix described requires less drive and space than a transistor unit and provides a storage facility.

621.384.612.22 1382
The Cambridge Electron Accelerator—M. S. Livingston and W. A. Shurcliff. (*Science*, vol. 134, pp. 1186–1193; October 20, 1961.) Description of the alternating-gradient 6-Gev electron synchrotron at Cambridge, Mass., capable of producing an electron beam of 6-kw mean intensity.

621.385.833 1383
Plans for a Large Electron Microscope—A. Franks and J. S. Halliday. (*Engineering, London*, vol. 192, pp. 94–95; July 21, 1961.) Report on a project for the design and construction of a 1-Mv electron microscope with a resolution of 1 Å.

621.385.833 1384
Measurement of the Dependence of Electron Microscope Image Contrast on Atomic Number, Beam Voltage and Aperture Diaphragm—L. Reimer. (*Z. angew. Phys.*, vol. 13, pp. 432–434; September, 1961.)

621.387.462 1385
Oxide-Stabilized Surface-Barrier Detectors—G. Amsel. (*Rev. Sci. Instr.*, vol. 32, p. 1253; November, 1961.) Comment on investigations of instability in high vacua and film deposition techniques.

621.396.969:534.2:551.508.5 1386
Acoustic Radar reads Wind Speed Remotely—(*Electronics*, vol. 34, p. 16; December 22, 1961.) Air velocity is measured by the Doppler shift of a radar signal reflected from a sound wave.

621.398:551.46.018 1387
Underwater Telemetry for Oceanographic Research—D. E. Campbell, R. J. Cyr, and C. Crosier. (*Electronics*, vol. 35, pp. 53–55; January 12, 1962.) Description of an experimental acoustic FM/FM telemetry system, for use in water, with a range of 10,000 ft.

621.398:551.507.362:621.382 1388
Transistors in Space—L. H. Brace. (*Wireless World*, vol. 68, pp. 102–105; March, 1962.) A description of circuits using solid-state devices for instrumentation and telemetry in rockets and satellites.

621.9:537.533/.534 1389
Electron or Ion Radiation as Microtools—M. v. Ardenne. (*Nachrtech.*, vol. 11, pp. 338–343; August, 1961.) Review of the use of focused electron or ion beams for machining in dimensions of the order of a micron or for forming microscopical objects. The main tools considered are electron and ion probes and reduced electron and ion images.

PROPAGATION OF WAVES

621.391.812.621:621.396.96 1390
A 'Layered' Exponential Model of Radar Refractivity—F. L. Martin and C. G. Waldron. (*J. Geophys. Res.*, vol. 66, pp. 4129–4135; December, 1961.) "A 'layered' exponential model for the vertical distribution of refractivity in the form $N=N_i \exp[-c_i(z-z_i)]$ is investigated. Here N_i and z_i are the refractivity and height, respectively, at a mandatory pressure level. The parameter c_i is the 'best fit' when $N=N_{i+1}$ is the value at the next level where $z=z_{i+1}$. A formula for c_i is derived and is found to give good agreement, layer by layer, with the above model. This model appears to have particular merits for the case of air-to-air radar tracking."

621.391.812.63 1391
Scattering of Radio Waves in the Ionosphere—B. R. Clemesha and R. W. Wright. (*Nature*, vol. 193, pp. 54–55; January 6, 1962.) The extra intensity of scattered MF waves from the 70-km level can be explained without recourse to intensified irregularities.

621.391.812.63 1392
Relation between Oblique and Ground Path Lengths in Ionospheric Propagation over a Curved Earth—P. J. D. Gething. (*Nature*, vol. 193, pp. 260–261; January 20, 1962.) Breit and Tuve's theorem ($P'=D \sec \Delta$) is modified for a curved earth and an ionosphere in which electron density varies only with height. Without assuming any layer distribution, close limits can be placed for any one parameter provided the other two are known.

621.391.812.63 1393
New Communications Aspects of Overseas Propagation in the Short-Wave Range—H. J. Albecht. (*Elektron. Rundschau*, vol. 15, pp. 536–540; November, 1961.) Outline of chordal-hop theory of ionospheric propagation (see, *e.g.*, 1288 of 1961) based on the results of the author's investigations from about 1953. 23 references.

621.391.812.63.029.45 1394
Average Decay Laws for V.L.F. Fields—J. R. Wait. (PROC. IRE, vol. 50, pp. 53–56; January, 1962.) A simple formula for average wave intensity is derived by averaging the square of field amplitude over the width of the earth-ionosphere waveguide, leading to a concise description of VLF attenuation rates.

621.391.812.63.029.45:551.507.362.2 1395
Penetration of the Ionosphere by Very-Low-Frequency Radio Signals—Interim Results of the LOFTI I Experiment—J. P. Leiphart, R. W. Zeek, L. S. Bearce, and E. Toth. (PROC. IRE, vol. 50, pp. 6–17; January, 1962.) Satellite telemetry signals indicated good reception of 18-kc/s transmissions up to distances of 10,000 miles. Time delays of up to 30 times the free-space value indicate low VLF propagation velocities. Whistler-mode propagation was observed.

RECEPTION

621.376.33 1396
Optimum Binary F.M. Reception using Discriminator Detection and I.F. Shaping—A. A. Meyerhoff and W. M. Mazer. (*RCA Rev.*, vol. 22, pp. 698–728; December, 1961.) An analysis and comparison of different systems on the basis of received carrier power required to achieve a given error probability per pulse.

621.391.822 1397
The Autocorrelation Function of Symmetrically Folded Gaussian Noise—T. H. Shepertycki. (*Canad. J. Phys.*, vol. 39, pp. 1851–1858; December, 1961.) Noise uniformly distributed in both amplitude and frequency of level crossings is generated by symmetrically folding Gaussian noise. The autocorrelation function of such noise is calculated and used to compute the power spectrum of low-pass Gaussian noise symmetrically folded at various folding levels for several folding slopes.

621.396.665:621–526 1398
Analysis of A.G.C. Loops—F. M. Gardner. (PROC. IRE, vol. 50, p. 96; January, 1962.) An alternative method of analysis to that of Victor and Brockman (1772 of 1960) is presented for determining the performance of AGC loops.

STATIONS AND COMMUNICATION SYSTEMS

621.391 1399
Integration and Effective Integration Time in the Sampling Correlator—C. Moeller. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 128–131; August, 1961.) See also 3533 of 1961.

621.391.63:621.372.8 1400
Optical Pipelines: a Tentative Assessment—C. C. Eaglesfield. (*Proc. IEE*, pt. B, vol. 109, pp. 26–32; January, 1962.) The electrical and mechanical problems relating to transmission at optical wavelengths along a 1-in-diameter pipe are discussed, allowing for 10-mile lengths between repeaters, an attenuation of 2.5 db/mile and bends not less than ½ mile radius. Methods of coupling the input and output are mentioned.

621.396.44:621.315.212 1401
An Introduction to the 12.5-Mc/s Coaxial-Line Transmission System—H. F. L. Cameron and G. E. Parrett. (*A.T.E. J.*, vol. 17, pp. 1–13; January, 1961.) A description is given of the complete system with details of ancillary equipment, characteristics and performance figures for a typical route. For papers on individual sections of the apparatus see *A.T.E. J.*, vol. 17,, pp. 14–45, January, 1961; vol. 17 pp. 47–91; April, 1961.

621.396.44:621.372.8 1402
The Waveguide as a Means of Transmission for Long-Distance Links—Armenante. (See 1129.)

621.396.65 1403
Factors Affecting the Design of Microwave Radio Links of High Capacity—J. P. Arnaud. (*Rev. Telegr. Electronica* (*Buenos Aires*), vol. 50, pp. 654–659; September, 1961.) Design problems and features of a system based on CCIR recommendations for multichannel radio links are discussed with reference to the planned Interamerican Telecommunication Network.

621.396.65:621.395.38 1404
The Application of V.F. Signalling to Rural Radio—C. B. Wooster and H. Dolan. (*A.T.E. J.*, vol. 17, pp. 118–129; July, 1961.) Details are given of the continuous-tone signaling system adopted in order to take advantage of the improved range obtained by using FM and PHM. See 2228 of 1958.

621.396.944 1405
Air-to-Undersea Communications—S. H. Durrani. (PROC. IRE, vol. 50, pp. 96–97; January, 1962.) An analytical note indicating that the best intercommunication system is obtained by using a vertical electric dipole in air and a horizontal electric dipole in the sea.

621.396.97:534.76 1406
Stereophonic Broadcasting—a Discussion of Technical Possibilities—E. Langer and V. Risak. (*Radioschau*, vol. 11, pp. 368–372, pp. 414–417, and pp. 462–465; September–November, 1961.) The principles of operation and characteristics of time-multiplex, frequency-multiplex and other practical methods of stereophonic broadcasting are summarized and compared.

SUBSIDIARY APPARATUS

621–52 1407
Theory of Stochastic Linear Systems with Gaussian Parameter Variations—J. C. Sam-

uels. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1782–1786; December, 1961.) A theory of linear systems with randomly varying parameters is developed under the assumption that the parameter processes are Gaussian processes obtained by linear filtering of white noise. A theory of mean and mean-square stability is given and applied to an RLC circuit with randomly varying capacitance. An error in a previous analysis (3649 of 1960) is corrected.

621–526:621.382.3–555.621 1408
High-Stability Temperature Controller for Transistors—H. Kemhadjian. (*Mullard Tech. Commun.*, vol. 6, pp. 122–131; December, 1961.) The control system uses two servomechanism stages which are electrically independent but thermally in series; an outer annular block is made to provide initial temperature control of the inner block which is thermally stabilized within itself.

621.3.087.4:621.395.625.3 1409
Single-Turn Recording Heads—H. J. Kump. (*Electronics*, vol. 35, p. 89; January 5, 1962.) Results of an experimental approach to the development of a single-turn head for a magnetic-drum storage system are noted. Optimum values of drum plating thickness, gap width and "write" current are shown in graphs.

621.316.722.078.3:621.387.322.22 1410
Voltage Stabilization by means of Trigger Tubes—G. Kerr and P. H. G. van Vlodrop. (*Electronic Applic.*, vol. 21, pp. 25–31; May, 1961.) Several cold-cathode trigger-tube circuits are described which give effective stabilization against fluctuating input voltage and current drain.

621.352 1411
The D.S.K. System of Fuel-Cell Electrodes—E. W. Justi and A. W. Winsel. (*J. Electrochem. Soc.*, vol. 108, pp. 1073–1079; November, 1961.) A description of various cells which have been constructed and experimental results.

TELEVISION AND PHOTOTELEGRAPHY

621.397 1412
Television Bandwidth and the Kell Factor—N. W. Lewis. (*Electronic Tech.*, vol. 39, pp. 44–47; February, 1962.) Attention is drawn to the need for stating the relevant conditions whenever the term "Kell factor" is used. Definitions of "pulse bandwidth" and "slot bandwidth" are suggested.

621.397.132 1413
The Assessment of the Colour Rendering of Television Installations by Photographic Means—H. Bergauer. (*Elektronik*, vol. 10, pp. 279–283; September, 1961.) The brightness of the screen image of a color test card is evaluated by reference to a grey scale. The suitability of various types and intensities of illumination for color television can also be assessed.

621.397.331.24 1414
The Enhanced-Scan, Post-Acceleration Kinescope—H. B. Law, L. Davne, and E. G. Ramberg. (*RCA Rev.*, vol. 22, pp. 603–622; December, 1961.) The scan power required for a monochrome picture tube can be greatly reduced by placing a near-hemispherical grid where the neck of the tube joins the funnel.

621.397.62:621.382.333 1415
The Influence of Alloy Diffused Transistors on Domestic Television Receiver Design—J. R. Goldthorp. (*Proc. IRE (Australia)*, vol. 22, pp. 645–652; October, 1961.) Applications of these transistors in the line timebases, RF and IF stages and the video amplifier are outlined. 25 references.

621.397.621 1416
Characteristics of Flywheel Synchronizing Circuits in Television Receivers—D. Maurice and E. R. Rout. (*Electronic Eng.*, vol. 34, pp. 77–81; February, 1962.) A theoretical analysis, which includes circuit response to all probable input conditions, is followed by a summary of performance measurements on six typical circuits used in television receivers.

621.397.621:621.391.837.22 1417
Effect of the Earth's Magnetic Field on Television Distortion—P. H. Phillips. (*Electronic Eng.*, vol. 34, pp. 41–42; January, 1962.) Trapezium distortion caused by the earth's magnetic field in 110° picture tubes may be half of the total permissible design tolerance.

TUBES AND THERMIONICS

621.382.002.2 1418
Ge or Si Junctions Made by the Surface Weld-Regrowth Process—T. C. Taylor and F. L. Yuan. (*Solid-State Electronics*, vol. 3, pp. 70–72; July, 1961.) *I/V* characteristics of *p-n* junctions made by this technique are illustrated. See 1332 of 1961 (Lesk).

621.382.23 1419
A Review of the Tunnel Diode—E. Adler and B. Selikson. (*Electronic Eng.*, vol. 34, pp. 8–13 and pp. 82–86; January and February, 1962.) A discussion of physical principles, characteristics and applications. 60 references.

621.382.23 1420
The Forward Transient Behaviour of Semiconductor Junction Diodes—Wen-Hsiung Ko. (*Solid-State Electronics*, vol. 3, pp. 59–69; July, 1961.) The forward transient in response to a step current is resolved into a junction-voltage component, due to the building up of excess-carrier density near the junction, and a bulk resistance component due to conductivity modulation. The two components can be determined analytically from the excess-carrier density junction for a simplified planar-junction model, and they provide an explanation of the three forms of transient observed, at various current levels.

621.382.23 1421
***p-n* Junction Charge-Storage Diodes**—J. L. Moll, S. Krakauer and R. Shen. (Proc. IRE, vol. 50, pp. 43–53; January, 1962.) Design theory is given for a new class of diode, characterized by a very abrupt interruption of reverse current in the turn-off transient.

621.382.23 1422
Explanation of One Type of R.F.-Induced Negative Resistance in Junction Diodes—J. C. McDadc. (Proc. IRE, vol. 50, p. 91; January, 1962.) An explanation is given for the negative-resistance regions observed in the *I/V* characteristics of *p-n* junction diodes with RF pumping (2804 of 1961).

621.382.23:535.37–15 1423
Some New Measurements of Infrared Luminescence in Tunnel Diodes—J. I. Pankove. (*J. Electrochem. Soc.*, vol. 108, pp. 998–1000; October, 1961.) The diodes are produced as integral source-detector structures which have very high optical coupling. The high sensitivity of the system reveals a variety of luminescence phenomena but the radiative mechanism has yet to be explained.

621.382.23:621.318.57:681.142 1424
The Design of Germanium Diodes used for Junction-Capacitance Parametrons—Y. Hiyama. (*Rev. Elec. Comm. Lab. Japan*, vol. 9, pp. 429–436; July/August, 1961.) Parametron diodes for ultra-high-speed computers must have a very low base resistance and a uniform junction capacitance. Design methods are described.

621.382.23:621.372.44 1425
Reverse-Current Anomaly in Germanium Diodes—M. Greenspan. (Proc. IRE, vol. 50, pp. 83–84; January, 1962.) Experiments at 156 Mc indicate that the reverse-current anomaly in varactor diodes is dependent upon surface effects as well as minority-carrier lifetime.

621.382.23:621.373.5 1426
A 5-Ampere Peak-Current Tunnel-Diode Oscillator at VHF—A. C. Scott. (Proc. IRE, vol. 50, p. 93; January, 1962.) Details of the structure of the oscillator are given together with an approximation method for determining its performance.

621.382.23:621.375.9:621.372.44 1427
Diffused Silicon Mesa Diodes for Use in Refrigerated Parametric Amplifiers—J. H. Forster and M. Uenohara. (Proc. IRE, vol. 50, pp. 82–83; January, 1962.) The noise figure of an amplifier was found to decrease steadily as the diode temperature was lowered to 100°K. Results obtained with several types of diode are discussed.

621.382.3 1428
Effect of High Surface Recombination Velocity on Transistor Gain—D. E. Vaughan. (*Brit. J. Appl. Phys.*, vol. 13, p. 44; January, 1962.) The point of inflection in published curves [see, *e.g.*, 3071 of 1954 (Herold)] relating the ratio of forward and reverse alphas to the surface recombination velocity is explained by a variable cross-sectional area for the emitter-collector path.

621.382.3:621.318.57 1429
The Silicon Switching Transistor—W. v. Münch and H. Salow. (*Nachrtech. Z.*, vol. 14, pp. 436–440; September, 1961.) The design, manufacture and characteristics of Si switching transistors are considered, in line with earlier investigations of Ge storage-type transistors (*e.g.*, 3311 of 1960)

621.382.333 1430
The Study of Large-Signal High-Frequency Effects in Junction Transistors using Analog Techniques—J. R. A. Beale and A. F. Beer. (Proc. IRE, vol. 50, pp. 66–77; January, 1962.) The base-emitter junction is represented by a transmission line lumped into several circuits. Effects of nonuniform current distribution are shown.

621.382.333 1431
The Relationship between Emitter Junction Recovery and "Wiggle" Effect—R. P. Nanavati and R. J. Wilfinger. (Proc. IRE, vol. 50, pp. 85–86; January, 1962.) A mechanism explaining the anomalous behavior of the saturated transistor collector waveform during turn-off, together with supporting experimental evidence, is presented.

621.382.333 1432
Thermal Transient Effects on Junction Transistors—T. C. Verster. (*J. Electronics and Control*, vol. 10, pp. 191–196; March, 1961.) The change in collector leakage current of a junction transistor is measured after the transistor has been subjected to thermal transients. The practical significance of the results is illustrated.

621.382.333 1433
Low-Voltage Negative Resistance in Junction Transistors—L. van Biljon. (*Electronic Tech.*, vol. 39, pp. 78–79; February, 1962.) The effect is caused by unequal division of base charge between an emitter and a collector of very different size when they are reverse biased.

621.382.333 1434
Base Resistance and Collector Capacitance of Alloy-Type Transistors—T. E. Price and F. J. Hyde. (*Proc. IEE*, pt. B, vol. 109, pp. 115–123; January, 1962.) If suitable values are chosen for $r_{bb'}$ and c_c a simple model is satisfactory. A more complicated model involving three extra elements is derived which shows why different methods of measurement of $r_{bb'}$ do not yield consistent results.

621.382.333 1435
Current Dependence of α_{eb} in the Alloy Junction Transistor—K. Sato and M. Tomono. (*Solid-State Electronics*, vol. 3, pp. 29–36; July, 1961.) An experimental study was made of the dependence of α_{eb} on the emitter current for variation of a) donor concentration in the base region, b) acceptor concentration in the emitter region, c) surface recombination velocity, and d) perfection of the junction.

621.382.333 1436
Breakdown Voltage in Power Transistors—R. Greenburg. (*Semiconductor Prod.*, vol. 4, pp. 21–25; November, 1961.) An expression is developed which relates collector diode breakdown BV_{CB0} to other avalanche effects. The variables in the expression are BV_{CB0} and the internal and external resistances in series with the internal base-emitter junction.

621.382.333:681.142 1437
Muliple-Collector Semiconductor Devices in Molecular Electronics—D. P. Kennedy and S. Gilman. (*Elec. Engrg.*, vol. 80, pp. 516–523; July, 1961.) The operation of a computer logic component which is based on current commutation between two hook collectors is analyzed. Equations encountered in the design of a two-collector structure are presented in graphical form.

621.382.333:681.142 1438
The Logic Potential of Molecular Electronics in the Multicollector Transistor—Earle. (See 1149.)

621.382.333.33 1439
Cut-Off Frequency of a Junction Transistor when Mobilities are Not Constant—R. L. Pritchard, T. Sugano and F. Koshiga. (PROC. IRE, vol. 50, pp. 91–93; January, 1962.) The effect of mobility variation on the cutoff frequency in practical drift-transistor structures is not as serious as indicated previously 3576 of 1961.

621.383.5 1140
A Photosensitive Single-Crystal *p-n* Junction in Lead Selenide—M. F. Kimmitt and A. C. Prior. (*J. Electrochem. Soc.*, vol. 108, pp. 1034–1038; November, 1961.) "A single crystal with a thin surface *p-n* junction has been grown from the vapour and its photovoltaic properties measured at various temperatures. The detector has high quantum efficiency but low electrical resistance, which is discussed."

621.383.5 1441
Single-Crystal Photoconductive Detectors in Lead Selenide—D. G. Coates, W. D. Lawson, and A. C. Prior. (*J. Electrochem. Soc.*, vol. 108, pp. 1038–1042; November, 1961.) Fabrication of the detectors depends on a new chemical etch which reduces the specimen thickness to a few microns and forms surfaces with a low carrier recombination velocity.

621.385.032.213.23 1442
The Poisoning of Barium-Nickel Matrix Cathodes—R. O. Jenkins and W. G. Trodden. (*J. Electronics and Control*, vol. 10, pp. 81–96; February, 1961.) An experimental study of the poisoning of the thermionic emission from Ba-Ni cathodes activated by Al and Ti hydride.

621.385.032.213.6 1443
Thermal Emissivity and Conductivity of Alumina Heater Coatings—N. Rudnick and J. J. Carrona. (*RCA Rev.*, vol. 22, pp. 623–647; December, 1961.) The transfer of heat to the cathode from an alumina-coated heater is improved by raising the emissivity of the heater surface by coating with graphite.

621.385.6:621.375.9:621.372.44 1144
Analysis of Fast-Wave Couplers for Transverse-Field Beam-Type Parametric Amplifiers—N. B. Chakraborty. (*J. Electronics and Control*, vol. 10, pp. 147–151; February, 1961.)

621.385.6:621.375.9:621.372.44 1445
The Application of Beam Cooling to Quadrupole Amplifiers—C. P. Lea-Wilson, T. J. Bridges, and J. C. Vokes. (*J. Electronics and Control*, vol. 10, pp. 261–272; April, 1961.) Beam expansion by space charge or in a tapered magnetic field can improve the noise figure of dc-pumped quadrupole amplifiers. A practical design of tube incorporating these techniques is described for use at 400 Mc. The upper frequency limit probably lies between 3 and 10 Gc.

ACOUSTICS AND AUDIO FREQUENCIES

534.78:621.395.665.1 1446
The Influence of Dynamic Compression and Expansion on Speech Intelligibility—G. Barrasch. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 187–195; October, 1961.) Intelligibility tests for German were carried out by means of a compandor system. The results are analyzed.

621.395.625.3:621.3.087.4:621.317.42 1447
Investigation of the Magnetic Recording Process with Step Functions—K. Teer. (*Philips Res. Repts.*, vol. 16, pp. 469–491; October, 1961.) The response to a recorded unit-step function is discussed and experiments are described which show this test signal to be suitable for measuring demagnetization effects, gap length, field distribution and the direction of magnetization.

621.395.625.3:621.391.822 1448
Noise in Magnetic Sound Recording—F. Hammon. (*Radio Mentor*, vol. 27, pp. 864–867; October, 1961.) The various causes of noise in magnetic tapes and tape recordlngs are reviewed, and methods of reducing noise are mentioned.

ANTENNAS AND TRANSMISSION LINES

621.372.22 1449
Synthesis of Nonuniform Transmission Lines and Riccati's Differential Equation—L. Gruner. (PROC. IRE, vol. 50, pp. 224–225; February, 1962.) A note on the synthesis of a line with given reflection coefficient varying along its length.

621.372.22:621.372.51 1450
Inhomogeneous Transmission Lines with Constant Loss Angle along the Line as Transformers of Minimum Physical Length between Two Lines with Equal Loss Angle—W. Jutzi. (*Arch. elekt. Übertragung*, vol. 15, pp. 423–428; September, 1961. Correction, vol. 15, p. 544; November, 1961.) The design principles used by Klopfenstein (976 of 1956) for a transmission-line taper are extended to inhomogeneous lossy lines.

621.372.8:537.56 1451
The Propagation of Slow Electromagnetic Waves in a Plasma Cable—Biener. (See 1508.)

621.372.81 1452
Random Imperfections in Waveguide—H. G. Unger. (*Arch. elekt. Übertragung*, vol. 15, pp. 393–401; September, 1961. Correction, vol. 15, p. 544; November, 1961.) Mode conversion due to random irregularities in waveguide is investigated, and the resulting attenuation and distortion effects are calculated. The H_{01} mode in circular waveguide is considered in particular.

621.372.823:621.372.83 1453
Reflection and Transmission with an H_{0n} Wave Impinging on a Conical Junction between Two Waveguides—G. Piefke. (*Arch. elekt. Übertragung*, vol. 15, pp. 444–454; October, 1961.) Formulas are derived for calculating the reflection and transmission coefficients, and curves of the reflection coefficient are given for the H_{01} mode in conical waveguide junctions with aperture angle up to 60°.

621.372.823:621.372.853.1 1454
Measurements on Dielectric-Loaded H_{01} Waveguide—H. Larsen and W. Janssen. (*Frequenz*, vol. 15, pp. 332–338; October, 1961.) The attenuation of various modes was measured on 50-mm-diameter Al tube with a dielectric coating of 0.1-mm thickness. The effects of curvature were also investigated. The coating helps to eliminate undesirable modes introduced by imperfections in the waveguide.

621.396.67:621.391.812.624 1455
Experimental Aperture Medium Coupling Loss—L. P. Yeh. (PROC. IRE, vol. 50, p. 205; February, 1962.) Calculated values of aperture-to-medium coupling loss are plotted as a function of the ratio of scatter angle to antenna beamwidth, together with a curve based on experimental data by various authors. The experimental curve is suggested as a good compromise for estimating coupling loss.

621.396.677.3 1456
Broad-Band Nonuniformly Spaced Arrays—J. D. Bruce and H. Unz. (PROC. IRE, vol. 50, p. 228; February, 1962.) Possible methods of approach to the problem of designing an optimum wide-band antenna array are considered.

621.396.677.73 1457
An Experimental Investigation of the Change in Radiation Patterns in the Fresnel's Region of Sectoral Electromagnetic Horn Antennas due to Shorting Grills—S. Hariharan and K. G. Nair. (*J. Inst. Telecommun. Engrs., India*, vol. 7, pp. 189–196; July, 1961.) The radiation pattern may be simply controlled and end-effects and irregularities due to mechanical defects eliminated, by proper positioning of the grills.

621.396.677.75 1458
New Leaky-Wave Antenna Designs—W. J. Getsinger. (*Electronics*, vol. 35, pp. 35–37; February 16, 1962.) Wire grids, dielectric loads and waveguide arrays are used in a range of antennas designed for operation at 4–11 Gc.

AUTOMATIC COMPUTERS

681.142 1459
The 'Pascal', a Fast Digital Electronic Computer for the Philips Computing Centre—W. Nijenhuis. (*Philips Tech. Rev.*, vol. 23, pp. 1–18; October 16, 1961.) A description of the design and operation of the computer, which is a binary parallel machine of single-address type with a word length of 42 bits. It incorporates

five different kinds of storage system including special "plug-board" and "modification" units.

681.142:621.318.34 1460
The Rectangular-Loop Ferrite Core as Storage Device for Data Processing Installations—P. Veith. (*Elektronik*, vol. 10, pp. 304–308; October, 1961.) Outline of fundamental principles underlying the storage mechanism and magnetization reversal process, with details of typical characteristics and dimensions of cores for use as storage elements. 48 references.

681.142:621.318.57:538.221 1461
Magnetic-Film Rods Provide High-Speed Memory—D. A. Meier. (*Electronics*, vol. 35, pp. 50–52; February 2, 1962.) The application of rod elements (1462 of 1959) in the development of a 128-word, 8-bit-per-word storage system with a 5-Mc cycle rate is described.

681.142:621.318.57:621.382.333 1462
kMc/s Planar Transistors in Microwatt Logic Circuitry—D. F. Allison, R. H. Beeson, and R. M. Shultz. (*Solid-State Electronics*, vol. 3, pp. 134–141; September, 1961.) The application of the UHF Si transistor to logic circuits at very low power is discussed. A four-stage shift register is described which operates at 10 μw per transistor stage.

681.142:621.391 1463
Pattern Recognition—P. Ercoli. (*Alta Frequenza*, vol. 30, pp. 619–630; September, 1961.) Review of the principles of pattern recognition on the basis of information theory. 216 references.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049.75 1464
Printed Circuits Made without Drawings—W. Gosling. (*Engineering, London*, vol. 192, pp. 180–181; August 11, 1961.) A "ring matrix" technique is described for rapid production, in the laboratory, of a circuit negative which is readily modified.

621.314.214:621.317.7 1465
The Helitran—C. G. Mayo and R. V. Harvey. (*Electronic Tech.*, vol. 39, pp. 98–102; March, 1962.) Two designs of RF transformer with continuously variable turns ratio forming a nearly perfect voltage divider are described. A "helitran" can simplify the design of the variable conductance control of three-terminal bridges with a transformer ratio arm.

621.318.433 1466
Coil Capacitances and Inductances of Single-Layer Cylindrical Coils for Different Current-Voltage Distributions over the Coil—E. Trzeba. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 161–165; October, 1961.)

621.318.57 1467
Possibilities of Realizing Logic (Boolean) Functions by means of 'Rectangular-Magnetic' Networks—U. Hölken. (*Arch. elekt. Übertragung*, vol. 15, pp. 482–494; October, 1961.) The network consists of idealized transfluxors with rectangular hysteresis loop.

621.318.57:538.632 1468
Using Hall Generators as Contactless Commutators—T. J. Marcus. (*Electronics*, vol. 35, pp. 43–45; February 9, 1962.) A sampling rate in excess of 30 kc is achieved by feeding a signal voltage into one input of a Hall generator and a switching waveform into the other. Amplification must be used to recover the signal loss but only one amplifier is needed regardless of the number of inputs.

621.318.57:621.382.23 1469
Designing Tunnel-Diode Circuits using Composite Characteristics—B. Rabinovici and J. Klapper. (*Electronics*, vol. 35, pp. 46–48; February 16, 1962.) With n tunnel diodes connected in series certain relations between their peak and valley currents and their final voltages can be satisfied so that the composite curve has 2^n-1 peaks, 2^n-1 valleys and 2^n stable positive regions. The use of this type of characteristic for binary addition, scaling and encoding is described.

621.318.57:621.383.4 1470
Solid-State Optoelectronic Commutator—R. D. Stewart. (*Electronics*, vol. 35, pp. 38–39; February 16, 1962.) Matching electroluminescent-photoconductor arrays can be packed into a volume <0.01 in^3 per switching element. The noise from an eight-channel binary output commutator is <12 μv for 2-Mc bandwidth, compared with an upper signal limit of 60 v.

621.319.4:621.318.2 1471
The Edge Effect of a Capacitor of Finitely Thick Plates with Application to Magnet Design—M. Müller. (*Frequenz*, vol. 15, pp. 286–293; September, 1961.) Conformal mapping is used to determine exactly the fringe capacitance and field-strength distribution of a thick-plate capacitor. General formulas and curves are given. The application to magnet systems intended for high-frequency devices is described.

621.372.413 1472
Novel Microwave Resonator—M. Lorant. (*Wireless World*, vol. 68, pp. 191–192; April, 1962.) A cavity resonator designed at the National Bureau of Standards based on Fabry-Perot interferometer technique, consists of two perforated sheets of metal 6–12 inches square forming the ends of a box. Microwave energy beamed on one end with correct end spacing produces a resonance Q of about 100,000.

621.372.5 1473
Symmetric Quadripoles—W. Herzog. (*Nachrtech. Z.*, vol. 14, pp. 502–511; October, 1961.) Further detailed description of the transformation of symmetric quadripoles and the cascade connection of bridge circuits to form filters. See also 405 of February.

621.372.5 1474
Analysis and Synthesis of Antimetrical Networks—J. B. Rudd. (*AWA Tech. Rev.*, vol. 12, pp. 25–48; January, 1962.) An extension of previous work on symmetrical reactance networks (see 1160 of April) to reactive ladders with resistance terminations.

621.372.54 1475
A Realization of the 'Error Curve System'—W. Giloi. (*Arch. elekt. Übertragung*, vol. 15, pp. 411–414; September, 1961.) The filter analyzed by Uhl (4029 of 1961) is discussed in terms of Küpfmüller's system theory.

621.372.543.2:534.143 1476
Transfer Characteristics of Electromechanical Coupling Filters as a Function of the Coupling Element—E. Trzeba. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 166–170; October, 1961.) The effect of manufacturing tolerances in respect of diameter and length of mechanical transmission-line elements is investigated. See also 4033 of 1961.

621.372.62 1477
A Contribution to the Synthesis of Resistive Three-Ports—G. Biorci and P. P. Civalleri. (*Alta Frequenza*, vol. 30, pp. 714–717; October, 1961. In English.) Algebraic and topological treatment of a special case of three-port network synthesis. For Italian version see *Alta Frequenza*, vol. 31, pp. 35–38; January, 1962.

621.372.62:518.4 1478
Fundamentals of Linear Graphs and their Applications to Networks without Transformers—L. Weinberg. (*Alta Frequenza*, vol. 30, pp. 726–737; October, 1961. In English.) The application of linear-graph theory to the analysis and synthesis of passive networks, and matrix methods of solution are described.

621.373:621.372.44 1479
The Switching-On of Two Oscillator Circuits which are Coupled by an Externally Controlled Reactance (Case of the Parametric Amplifier)—H. Kaden. (*Arch. elekt. Übertragung*, vol. 15, pp. 475–481; October, 1961.) Extension of earlier investigations (413 of February) to the case of coupled resonant circuits.

621.373:621.372.81 1480
Investigation of the Possibilities of a Non-reactive Parallel Connection of Two Oscillators in the Short-Wave Range—W. Hassenpflug and H. Kumpfert. (*Frequenz*, vol. 15, pp. 294–299; September, 1961.) Scattering matrices are used to calculate the characteristics of three- and four-port networks, and a comparison of their suitability for parallel connection is made. Application to waveguide circuits is discussed.

621.373.029.6 1481
Defining the Coherence of a Signal—R. N. Bracewell. (Proc. IRE, vol. 50, p. 214; February, 1962.) Comment on 2502 of 1961 (Golay).

621.373.42 1482
An Analysis of a Class of Variable-Frequency Sinusoidal Oscillators using a Single Active Element—S. Caputo and W. H. Highleyman. (Proc. IRE, vol. 50, pp. 162–170; February, 1962.) An analysis is given of a class of oscillators requiring a single active element with an electronically variable mutual conductance g_m. The oscillation frequency is directly or inversely proportional to $\sqrt{g_m}$. Two experimental circuits are described and compared with theory.

621.373.42 1483
An Investigation of Nonlinear Distortion in Grid-Modulated Oscillators caused by the Bottom Bend of the Static Valve Characteristic—N. S. Stanulov. (*Nachrtech.*, vol. 11, pp. 419–421; September, 1961.)

621.373.421.13:621.374.4 1484
Review of the Present State of Crystal Control and Frequency Synthesis—K. Fischer. (*Frequenz*, vol. 15, pp. 324–332; October, 1961.) Description of basic circuits constituting various frequency-synthesizing systems.

621.373.43:621.382.23 1485
One-Tunnel-Diode Flip-Flop—J. F. Banzhaf, III, and H. S. Katzenstein. (Proc. IRE, vol. 50, p. 212; February, 1962.) Report on the operation of a circuit similar to one given in 1761 of 1961 (Kaenel) with oscillograms showing triggering and switching modes.

621.373.431.1:621.382.233 1486
An Astable Four-Region Multivibrator—G. Strull and W. M. Kaufman. (*Solid-State Electronics*, vol. 3, pp. 110–118; September, 1961.) The multivibrator operation of a four-region semiconductor structure is analyzed and its temperature instability is discussed. Results obtained with a five-region structure are also given.

621.374:621.396.962.3 1487
Pulse Compression without Dispersive Networks—E. Hüttmann. (*Nachrtech.*, vol. 11,

pp. 422–425; September, 1961.) Pulse compression by means of a three-dimensional correlator using light modulation is described. The application to radar systems is discussed.

621.374.4:621.318.134 1488
Saturation Effects in Ferrite Frequency Doublers Operating in the Uniform Precession Mode—B. A. Auld. (*J. Appl. Phys.*, vol. 33, pp. 112–114; January, 1962.) Three distinct saturation mechanisms occurring in ferrite frequency doublers are described. An approximate nonlinear equation of motion, including the effect of the reaction field, is obtained and solved for a particular case.

621.374.5:534.2–8:535.5 1489
A Variable Ultrasonic Electro-optical Delay Line and a New Ultrasonic-Optical Effect in Fused Quartz—W. Liben and L. A. Twigg, Jr. (*J. Appl. Phys.*, vol. 33, p. 249; January, 1962.) A variable delay line for RF pulses is described in which unpolarized light is modulated by the RF signal passing through a quartz bar and is detected by a photomultiplier. The operation of the system is unexplained.

621.374.5:537.228.1 1490
Quartz Delay Lines: the State of the Art—V. J. Hammond. (*Brit. Commun. Electronics*, vol. 9, pp. 104–110; February, 1962.) A summary of available information on geometry, performance and applications of ultrasonic delay lines. 22 references.

621.375.9:538.569.4 1491
Transient Phenomena in Ruby Maser—F. Saito. (*J. Phys. Soc. Japan*, vol. 16, pp. 2592–2593; December, 1961.) A note on time lags observed in the build-up of oscillations in a pulsed three-level maser operating at 9.4 Gc with pump frequency 24 Gc.

621.375.9:538.569.4 1492
On the Problem of Pulsed Oscillations in Ruby Maser—G. Makhov. (*J. Appl. Phys.*, vol. 33, pp. 202–204; January, 1962.) The nonlinearity necessary for the existence of a pulsed mode of operation is shown to be due to the interaction between the Cr electrons and the distant Al^{27} nuclei.

621.375.9:538.569.4:621.3.018.41(083.74) 1493
Double-Beam Masers as Primary Frequency Standards—De Prins, Menoud, and Kartaschoff. (See 1647.)

621.375.9:621.372.44 1494
Origin of Noise in a Ferromagnetic Parametric Amplifier—R. T. Denton and W. B. Snow. (PROC. IRE, vol. 50, p. 208; February, 1962.) Further measurements on a ferromagnetic parametric amplifier with longitudinal pumping indicate that the exceptionally high noise figure previously reported [*J. Appl. Phys.*, vol. 32, Suppl., pp. 300S–307S; March, 1961 (Denton)] is not thermal in origin.

621.375.9:621.372.44 1495
An Extremely-Low-Noise 6-Gc/s Nondegenerate Parametric Amplifier—M. Uenohara. (PROC. IRE, vol. 50, pp. 208–209; February, 1962.) Preliminary note on an experimental amplifier which was operated at room and liquid-nitrogen temperatures. A system noise temperature $<60°K$ was achieved.

621.375.9:621.372.44:621.374 1496
Microwave-Carrier Modulation-Demodularion Amplifiers and Logic Circuits—W. Eckhardt and F. Sterzer. (PROC. IRE, vol. 50, pp. 148–161; February, 1962.) Applications of parametric amplifiers are described in wideband video modulation-demodulation amplifiers and ultra-high-speed M-D logic circuits with possible repetition rates of the order of 10^9/sec.

621.375.9:621.382.23 1497
The Tunnel-Diode Superregenerative Amplifier—A. G. Jordan and R. Elco. (*J. Electronics and Control*, vol. 11, pp. 65–79; July, 1961.) The simplicity of the circuitry required and the characteristics of tunnel diodes make superregenerative amplifiers very attractive for applications where high gains are required. The noise performance of maser and parametric amplifiers is superior.

GENERAL PHYSICS

537.533 1498
Progress in Field-Emission Work-Function Measurements of Atomically Perfect Crystal Planes—R. D. Young and E. W. Müller. (*J. Appl. Phys.*, vol. 33, pp. 91–95; January, 1962.)

537.533:537.56 1499
The Penetration of an Electron Beam through a Plasma: Part 1—General Considerations—Amplification and Overstability—S. V. Yadavalli. (*J. Electronics and Control*, vol. 10, pp. 437–448; June, 1961.) The problem is treated from the point of view of the double-stream amplifier, the resistive- and inductive-envelope amplifier, and stability theory.

537.533:538.691 1500
The Orbit of a Charged Particle in a Constant Magnetic Field and a Sinusoidal Electric Field—N. Anderson. (*J. Electronics and Control*, vol. 10, pp. 449–451; June, 1961.) Explicit expressions are obtained for the particle orbit assuming that the effect of the electric field on the particle is merely to produce a perturbation on the motion which it would describe in the absence of the field.

537.533.7 1501
Experimental Demonstration of the Phase Shift of Electron Waves by the Magnetic Vector Potential—H. Boersch, H. Hamisch, K. Grohmann, and D. Wohlleben. (*Z. Phys.*, vol. 165, pp. 79–93; October 18, 1961.) Report on investigations with an electron-optical interferometer. See also 2307 of 1961 (Boersch, et al.).

537.56 1502
The Noise Temperature of a Plasma—G. H. Plantinga. (*Philips Res. Repts.*, vol. 16, pp. 462–468; October, 1961.) Using a current-source method an expression for noise temperature is derived, identical with that for plasma radiation temperature derived by Bekefi, *et al.* (*Phys. Fluids*, vol. 4, pp. 173–176; February, 1961), but valid under more general assumptions. The application of the expression is not confined to transparent plasmas.

537.56 1503
Dielectric Constant of Plasma—R. N. Franklin and G. Francis. (*J. Electronics and Control*, vol. 11, pp. 54–55; July, 1961.) The definition of dielectric constant used by Gallop, *et al.* (1209 of April) is criticized on theoretical grounds. In reply (*J. Electronics and Control*, vol. 11, pp. 225–226; September, 1961) the authors point out that the definition is justified on experimental evidence relating to the particular conditions under discussion.

537.56:538.566 1504
Emission, Absorption and Conductivity of a Fully Ionized Gas at Radio Frequencies—L. Oster. (*Rev. Mod. Phys.*, vol. 33, pp. 525–543; October, 1961.) Classical and quantum-mechanical calculations are compared, yielding the emission spectrum of free electrons in the Coulomb field of positive ions.

537.56:538.566 1505
Backward Waves on Isotropic Plasma Slabs—A. A. Oliner and T. Tamir. (*J. Appl. Phys.*, vol. 33, pp. 231–233; January, 1962.) If the relative dielectric constant of the plasma becomes negative, backward surface waves can be developed on a lossless, homogeneous and isotropic plasma slab.

537.56:538.566:538.6 1506
Magnetic Effects in a Plasma Column Irradiated with Microwaves—W. D. Hershberger and I. Petroff. (*J. Appl. Phys.*, vol. 33, pp. 227–228; January, 1962.) The radius of gyration of a plasma column is determined by imparting a coherent circular orbital motion to the electrons in the column at its principal resonance frequency. This is accomplished by irradiating the column with two incoming waves of the same frequency but 90° out of phase. When the electric fields are correctly aligned, a magnetic moment is developed.

537.56:538.63:061.3 1507
Magnetic-fluid Dynamics—(*Rev. Mod. Phys.*, vol. 32, pp. 695–1028; October, 1960. Discussion.) 54 papers presented at the symposium sponsored by the International Union of Theoretical and Applied Mechanics, in cooperation with the National Academy of Sciences and the National Research Council, held at Williamsburg, Va., and Washington, D. C., in January, 1960.

537.56:621.372.8 1508
The Propagation of Slow Electromagnetic Waves in a Plasma Cable—G. Biener. (*Z. angew. Phys.*, vol. 13, pp. 457–465; October, 1961.) A phase-difference method of measurement is described which enables the propagation parameters of a traveling wave in a plasma to be determined, including the direction of phase and group velocities. See also 1121 and 2157 of 1961 (Schumann).

538.566:535.43 1509
On the Axial Echo Area of the Cone-Sphere Shape—E. M. Kennaugh and D. L. Moffatt. (PROC. IRE, vol. 50, p. 199; February, 1962.) Initial results of a study of the back-scattering from a cone-sphere are given. Comparison is made between the measured and calculated axial echo areas of a 30° cone-sphere.

538.569.4:538.221 1510
Two-Magnon Processes in Ferromagnetic Relaxation—M. Sparks. (*Phys. Rev. Lett.*, vol. 8, pp. 54–55; January 15, 1962.) A theory is developed from the assumption that all magnons of equal energy are so tightly coupled that they may be considered as a unit in any process involving degenerate magnons.

538.569.4:538.221:621.318.134 1511
Propagation of Spin Waves—B. Lüthi. (*J. Appl. Phys.*, vol. 33, pp. 244–245; January, 1962.) Theoretical considerations show that coherent spin waves can be propagated in a ferrite material if the microwave field penetrates no more than a distance λ_0 into the specimen.

538.569.4:621.375.9:535.61–1 1512
Infrared Oscillations from $CaF_2:U^{3+}$ and $BaF_2:U^{3+}$ Masers—H. A. Bostick and J. R. O'Connor. (PROC. IRE, vol. 50, pp. 219–220; February, 1961.) Results obtained from the operation of these masers are given. Trains of damped oscillations were observed.

538.569.4:621.375.9:535.61–1 1513
Continuous Operation of the $CaWO_4:Nd^{3+}$ Optical Maser—L. F. Johnson, G. D. Boyd,

K. Nassau, and R. R. Soden. (PROC. IRE, vol. 50, p. 213; February, 1962.) Preliminary report on the experimental apparatus and results achieved. Continuous operation was maintained for about 12 sec.

538.569.4:621.375.9:535.61–2 1514
Lasers—K. D. Harris. (*Electronic Tech.*, vol. 39, pp. 86–94; March, 1962.) Review of recent developments and applications.

538.569.4:621.375.9:535.61–2 1515
Theory of Relaxation Oscillations in Optical Masers—R. Dunsmuir. (*J. Electronics and Control*, vol. 10, pp. 453–458; June, 1961.) A theoretical explanation is given of the intense short "spikes" observed in the output of optical masers [*e.g.*, 657 of 1961 (Collins, *et al.*)]. A simple formula is derived for the time interval between them and the rate at which they decay to a constant level.

538.569.4:621.375.9:535.61–2 1516
Visual Display of Isolated Optical-Resonator Modes—H. Kogelnik and W. W. Rigrod. (PROC. IRE, vol. 50, p. 220; February, 1962.) A technique for producing pure modes in a laser cavity is described. Two concave mirrors forming a nearly spherical cavity are used.

538.569.4:621.375.9:535.61–2 1517
Coupling of Laser Rods—J. I. Masters. (PROC. IRE, vol. 50, pp. 220–221; February, 1962.) Interference was observed between the oscillations produced in two parallel ruby laser rods coupled by a 90° prism. Results indicate that the coupling of independently pumped lasers is feasible.

538.569.4:621.375.9:535.61–2 1518
Measurements of the Laser Output—S. Koozekanani, P. P. Debye, A. Krutchkoff, and M. Ciftan. (PROC. IRE, vol. 50, p. 207; February, 1962.) Measurements of energy output were made by means of a simulated black-body absorber; the accuracy of the system was sufficient to measure a minimum energy of 10^{-2} joules. A plot of laser output as a function of pump input energy is reproduced.

538.569.4:621.375.9:535.61–2 1519
Propagation in Laser Crystals—J. I. Masters and G. B. Parrent, Jr. (PROC. IRE, vol. 50, pp. 230–231; February, 1962.) An example is given of ring structure in a far-field pattern from a laser. This may be absent, but fringes may still be obtainable from a two-slit system.

538.569.4:621.375.9:535.61–2 1520
Stimulated Light Emission by Optical Pumping and by Energy Transfer in Organic Molecules—D. J. Morantz, B. G. White, and A. J. C. Wright. (*Phys. Rev. Lett.*, vol. 8, pp. 23–25; January 1, 1962.) Observations of stimulated light emission in organic glass matrices are described, particularly in glass containing approximately 0.02 per cent of benzophenone and of naphthalene in which energy is absorbed by the benzophenone and transferred to the naphthalene

538.569.4:621.375.9:535.61–2 1521
Optical Mixing—M. Bass, P. A. Franken, A. E. Hill, C. W. Peters, and G. Weinreich. (*Phys. Rev. Lett.*, vol. 8, p. 18; January 1, 1962.) A report of the observation of the sum frequency of two ruby laser beams of different frequencies, in the 3470-Å region, incident simultaneously on a crystal of triglycine sulphate.

538.569.4:621.375.9:535.61–2 1522
Mixing of Light Beams in Crystals—J. A. Giordmaine. (*Phys. Rev. Lett.*, vol. 8, pp. 19–20; January 1, 1962.) Plane light waves provided by an intense unfocused beam of a ruby laser are used to produce second-harmonic radiation in a KDP crystal.

538.569.4:621.375.9:535.61–2 1523
Effects of Dispersion and Focusing on the Production of Optical Harmonics—P. D. Maker, R. W. Terhune, M. Nisenoff, and C. M. Savage. (*Phys. Rev. Lett.*, vol. 8, pp. 21–22; January 1, 1962.) The generation of blue light by the incidence of red light from a ruby laser upon quartz and KDP is examined. Particular attention is given to the variation in blue-light intensity with crystal orientation.

538.569.4:621.375.9:535.61–2 1524
Nonlinear Optical Effects—R. Braunstein. (*Phys. Rev.*, vol. 125, pp. 475–477; January 15, 1962.) The possibility is discussed of producing harmonic generation and mixing at infrared and visible frequencies by means of radiation from optical masers.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164 1525
Some Radio Astronomy Techniques—R. C. Jennison. (*J. Brit. IRE*, vol. 23, pp. 121–127; February, 1962.) A review of modern techniques.

523.164.32 1526
Spectral Observations of Solar Radio Bursts: Part 2—Slow-Drift Bursts and Coronal Streamers—A. Maxwell and A. R. Thompson. (*Astrophys. J.*, vol. 135, pp. 138–150; January, 1962.) The characteristics and origin of slow-drift bursts (spectral type II) are determined from data recorded in the frequency ranges 25–580 and 2100–3900 Mc at Fort Davis, Tex., during the period October, 1956–December, 1960. The equipment used is described in Part 1: *Astrophys. J.*, vol. 133, pp. 643–648; March, 1961 (Thompson).

523.165 1527
Mechanism of Cosmic-Ray Storms Inferred from some Statistical Results—K. Sinno. (*J. Radio Res. Labs., Japan*, vol. 8, pp. 289–299; September, 1961.) A statistical analysis of results obtained during a four-year period, including the IGY, relating to the propagation time of cosmic-ray storms and the heliographic position of solar flares.

523.165 1528
The 27-Day Period of Cosmic Radiation—W. Zwanzig. (*Z. Naturforsch.*, vol. 16a, pp. 1237–1239; November, 1961.) The existence of a persistent 27.2-day periodicity of the intensity of cosmic radiation is proved from an analysis of recordings at Huancayo, Peru, and Halle, Germany.

523.165 1529
Trapped Proton and Cosmic-Ray Albedo Neutron Fluxes—S. C. Freden and R. S. White. (*J. Geophys. Res.*, vol. 67, pp. 25–29; January, 1962.) A rocket-borne emulsion stack was launched at 41°N to an altitude of 1185 km. A proton energy spectrum above 17 Mev was calculated and its shape near 20 Mev interpreted by assuming a minimum in the cosmic-ray albedo neutron spectrum.

523.165 1530
Absolute Electron Intensities in the Heart of the Earth's Outer Radiation Zone—B. J. O'Brien, J. A. Van Allen, C. D. Laughlin, and L. A. Frank. (*J. Geophys. Res.*, vol. 67, pp. 397–403; January, 1962.) Previous estimates from Geiger counters of the electron flux above 20 kev are shown to be too large by a factor of 10^3. The high count rates are due not to electron bremsstrahlung but to directly penetrating electrons of energy >1 Mev.

523.165:523.7 1531
Time Variations of the Energy Spectrum of Solar Cosmic Rays in Relation to the Radiation Hazard in Space—D. K. Bailey. (*J. Geophys. Res.*, vol. 67, pp. 391–396.; January, 1962.) Results from a number of solar cosmic-ray events are used to estimate the highest level of integrated proton flux likely to be encountered.

523.165:550.38 1532
Particle Motion in the Equatorial Plane of a Dipole Magnetic Field—E. H. Avrett. (*J. Geophys. Res.*, vol. 67, pp. 53–58; January, 1962.) For the motion of a high-energy particle in a dipole field a correction to the usual drift velocity is given. The new result must be used when the radius of gyration of the particle approaches the scale of the field.

523.165:551.507.362.1 1533
Ionized Gas and Fast Electrons in the Vicinity of the Earth and in Interplanetary Space—K. I. Gringauz, V. G. Kurt, V. I. Moroz, and I. S. Shklovskiĭ. (*Isk. Sput. Zemli*, no. 6, pp. 108–112; 1961. English trans., *Planet-Space Sci.*, vol. 9, pp. 21–25; January/February, 1962.) Measurements made during the flight of the second Soviet space rocket are described. It is concluded that the electron flux in the second radiation belt does not exceed 2×10^7 cm^{-2}/sec. Evidence is also provided for the existence of a third outermost belt 50,000–70,000 km from the earth's surface.

523.165:551.507.362.2 1534
Observations of the Van Allen Radiation Regions during August and September 1959: Part 3—The Inner Belt—R. A. Hoffman, R. L. Arnoldy, and J. R. Winckler. (*J. Geophys. Res.*, vol. 67, pp. 1–12; January, 1962.) Ionization-chamber and G-M counter data from Explorer VI are used to obtain the two constants in an assumed energy spectrum for inner protons of the belt protons of the form $dN = N_0E^{-7}dE$. Electron fluxes of low energy are estimated from scintillation counts. Part 2: 1243 of April.

523.165:551.507.362.2 1535
The Detection of Electrons with Energies of Approximately 10 keV in the Upper Atmosphere—V. I. Krasovskiĭ, I. S. Shklovskiĭ, Yu. I. Gal'perin, E. M. Svetlitskiĭ, Yu. M. Kushnir, and G. A. Bordovskiĭ. (*Isk. Sput. Zemli*, no. 6, pp. 113–126; 1961. English trans., *Planet-Space Sci*; vol. 9, pp. 27–40; January/February, 1962.) Fluorescent-screen indicators on the third Soviet satellite recorded electron fluxes at altitudes up to 1900 km over the southern region of the Pacific Ocean. The dependence of electron and energy fluxes on direction relative to the earth's field is examined. It is suggested that the energy flux is sufficient to cause heating in the F region.

523.165:551.594.5 1536
Bifurcation of the Outer Van Allen Belt and Related Auroral Phenomena—H. L. Stolov. (*J. Geophys. Res.*, vol. 67, pp. 404–406; January, 1962.) The two parts of the outer belt are associated with two separate regions of auroral activity.

523.3:621.396.96 1537
Irregular Lunar Reflection Polarization Changes Noted in the Presence of Aurora—J. Klobuchar, J. Aarons, H. Whitney, and G. Kantor. (*J. Geophys. Res.*, vol. 67, pp. 111–113; January, 1962.) Observations made during a lunar experiment carried out between Sagamore Hill, Mass., and Jodrell Bank show fast irregular changes in signal polarization while a

visible aurora occurred on one leg of the bistatic path. An explanation is given.

523.5 1538
A New Technique for Investigation of Meteor Echoes at U.H.F.—G. H. Pettengill. (*J. Geophys. Res.*, vol. 67, pp. 409–411; January, 1962.) The application of radar Doppler measurements to the study of meteor echo characteristics is described.

523.75 1539
Solar Protons and α Particles from the September 3, 1960, Flares—S. Biswas, P. S. Freier, and W. Stein. (*J. Geophys. Res.*, vol. 67, pp. 13–24; January, 1962.) A report of balloon observations at Minneapolis during a series of major solar flares.

550.385.37 1540
On the Frequency of Occurrence and Amplitude Spectrum of the Geomagnetic Field Pulsations—O. V. Bolshakova and K. Yu. Zybin. (*Ann. Géophys.*, vol. 17, pp. 345–350; In English. October–December, 1961.) The results of investigations of geomagnetic micropulsations, observed at the Soviet flux-measurement stations during IGY and IGC are presented. Diurnal variations of amplitude and of frequency of occurrence of micropulsations having different periods are investigated.

550.385.4:523.75 1541
Theoretical Determination of the Form of the Boundary of the Solar Corpuscular Stream produced by Interaction with the Magnetic Dipole Field of the Earth—J. R. Spreiter and B. R. Briggs. (*J. Geophys. Res.*, vol. 67, pp. 37–51; January, 1962.)

550.385.4:551.510.536 1542
New Experimental Evidence of the Effect of Magnetic Storms on the Magnetosphere—D. L. Carpenter. (*J. Geophys. Res.*, vol. 67, pp. 135–145; January, 1962.) New methods of whistler analysis [4149 of 1961 (Smith and Carpenter)] have been used to study the effect of magnetic storms on the time delay at whistler nose frequencies. During the late phases of magnetic storms these time delays are reduced. There is evidence that these changes in delay represent changes in the electron density in the magnetosphere.

551.507.362.1 1543
The First Italian Launch of a Sounding Rocket for Upper-Atmosphere Research—L. Broglio. (*Ricerca sci.*, vol. 1, pp. 307–325; October–December, 1961.) Review of technical problems and the organization and equipment employed for a sodium cloud experiment carried out from Sardina on January 12, 1961. Results are given and discussed.

551.507.362.2 1544
The Classification of the Motions of an Artificial Earth Satellite about its Centre of Mass—V. V. Beletskiĭ. (*Isk. Sput. Zemli*, no. 6, pp. 11–32; 1961. English trans., *Planet-Space Sci.*, vol. 9, pp. 47–65; January/February, 1962.) An analysis is given of aerodynamic and gravitational perturbations, taking account of orbital regression. The aerodynamic effects due to retardation of the satellite rotation are not considered.

551.507.362.2 1545
On the Secular Variations of the Elements of Satellite Orbits—G. N. Ward. (*Proc. Roy. Soc. (London) A*, vol. 266, pp. 130–142; February 27, 1962.)

551.507.362.2 1546
On the Long-Period Effects in the Motion of an Artificial Satellite caused by the Ellipticity of the Equator of the Earth—P. Musen. (*J. Geophys. Res.*, vol. 67, pp. 313–319; January, 1962.)

551.507.362.2 1547
Effect of Ellipticity of the Equator on 24-Hour Nearly Circular Satellite Orbits—L. Blitzer, E. M. Boughton, G. Kang, and R. M. Page. (*J. Geophys. Res.*, vol. 67, pp. 329–335; January, 1962.)

551.507.362.2 1548
Predicting the Lifetimes of Artificial Satellites in Theory and Practice—D. G. King-Hele. (*Nature*, vol. 193, pp. 638–639; February 17, 1962.) Possible errors involved in calculating lifetimes from simplified formulas are considered and methods of error reduction are suggested.

551.507.362.2 1549
Prelimiary Results of Radiation Measurements from the Tiros III Meterological Satellite—W. Nordberg, W. R. Bandeen, B. J. Conrath, V. Kunde, and I. Persano. (*J. Atmos. Sci.*, vol. 19, pp. 20–30; January, 1962.) Measurements of visible and infrared radiation are presented, together with television pictures of cloud patterns. Values of radiation fluxes and albedos are derived.

551.507.362.2:523.164 1550
Use of *Z*-Mode Propagation for Observing Cosmic Radio Noise from Earth Satellites—G. R. A. Ellis. (*Nature*, vol. 193, pp. 862–863; March 3, 1962.) The use of *Z*-mode propagation for reception of signals from satellites above the height of maximum ionization density gives an effective improvement in angular resolution, stability of radiation pattern, and pencil-beam configuration.

551.507.362.2:523.165 1551
Energy Detector for Satellites—J. W. Freeman. (*Electronics*, vol. 35, pp. 42–43; January 26, 1962.) A description of a CdS detector used in Explorer XII and Injun I to measure the integrated energy flux of low-energy electrons and protons.

551.510.535 1552
Electron Temperature Evidence for Non-thermal Equilibrium in the Ionosphere—N. W. Spencer, L. H. Brace, and G. R. Carignan. *J. Geophys. Res.*, vol. 67, pp. 157–175; January, 1962.) Measurements of ion density and electron temperature from four rocket flights by "dumbbell-shaped" Johnson-Malter-type probes, are presented. The method of analysis is described in detail, with examples. Electron temperatures about double the 1959 ARDC gas temperatures were found from 100–400 km.

551.510.535 1553
Electron Distribution in the Ionosphere over Trivandrum—C. S. R. Rao and S. C. Bose. (*J. Inst. Telecommun. Engrs., India*, vol. 7, pp. 181–188; July, 1961.) The results are given of an analysis of $N(h)$ profiles obtained from $h'(f)$ records on selected quiet days during June, September, and December, 1959, and March, 1960.

551.510.535 1554
The Behaviour of the Lower Ionosphere near Sunrise—J. K. Hargreaves. (*J. Atmos. Terr. Phys.*, vol. 24, pp. 1–7; January, 1962.) In the lower D region, a temporary increase in electron density is predicted at the time of ionospheric sunrise. A decrease in the height of reflection of VLF waves and a decrease in the signal strength of LF waves at sunrise are quoted as evidence for the existence of the temporary layer.

551.510.535 1555
The Determination of D-Region Electron Densities from Observations of Cross-Modulations—R. E. Barrington and E. Thrane. (*J. Atmos. Terr. Phys.*, vol. 24, pp. 31–42; January, 1962.) The Bailey and Martin expressions for cross modulation are not sufficiently accurate; new expressions have been derived and used to determine D-region electron densities. Near sunrise a nearly uniform layer is created almost simultaneously between 60 and 80 km and there are no striking changes during the rest of the day. D-region theory is also discussed.

551.510.535:523.75:621.391.812.63 1556
Ionospheric Effects Associated with the Solar Flare of September 28, 1961—Davies. (See 1674.)

551.510.535:539.16 1557
Effects of Nuclear Explosions on the Ionosphere—W. Dieminger and H. Kohl. (*Nature*, vol. 193, pp. 963–964; March 10, 1962.) An increase of about 100 per cent in the electron density of the F layer over Lindau was observed at the time of transit of the shock wave from the 50-megaton-yield nuclear bomb over Novaya Zemlya on October 30, 1961. Relevant ionograms and data are illustrated.

551.510.535:550.385.37 1558
The Relation of Magnetic Micropulsations to Electric-Current and Space-Charge Systems in the Lower Ionosphere—H. A. Bomke. (*J. Geophys. Res.*, vol. 67, pp. 177–181; January, 1962.) From observations made in 1960 using a large wire loop, theory is developed to suggest that micropulsations in the 1-cps range are associated with absorption of auroral particles in the ionosphere, and in the 0.1–0.01 cps range are the result of the absorption and reflection of hydromagnetic waves in the lower ionosphere.

551.510.535:550.385.4 1559
Total Electron Content of the Ionosphere over Singapore during a Magnetic Disturbance—L. Bonvini and C. Clarke. (*Nature*, vol. 193, pp. 864–865; March 3, 1962.) Observations made during a disturbance characterized by a negative phase show a corresponding decrease in total electron content of the ionosphere.

551.510.535:550.386 1560
Spread-F and Geomagnetic Activity—C. V. S. Rao and S. M. Mitra (*J. Geophys. Res.*, vol. 67, pp. 127–134; January, 1962.) On magnetically quiet days the occurrence of spread F at Trivandrum, near the geomagnetic equator, is regular; it begins after sunset, reaches a peak at 2000 LMT, and falls off slowly towards morning. On stormy days the frequency of occurrence is lower and the behavior is less regular. The effect of storms is least in summer. Some of the observations are in agreement with the theory of Martyn (1555 of 1959).

551.510.535:551.507.362.1 1561
Rocket Measurements of the Upper Ionosphere by a Radio Propagation Technique—S. J. Bauer and J. E. Jackson. (*J. Brit. IRE*, vol. 23, pp. 139–143; February, 1962.) A example of measurement of the electron-density profile up to 620 km by means of the two-frequency CW technique is presented, including the determination of inferred scale height and temperature of the upper ionosphere. A correction procedure is outlined, necessary for the determination of local electron density data.

551.510.535:551.507.362.2:621.391.812.63 1562
Diurnal Variations in the Ionosphere deduced from Satellite Radio Signals—G. H Munro. (*J. Geophys. Res.*, vol. 67, pp. 147–156; January, 1962.) Observations of the

Faraday fading rate at Sydney, Australia, from Sputnik III have been used in a simple way to obtain diurnal and seasonal electron-content variations. Secondary maxima occur at 1800 LMT in both seasons and 0500 in winter: the diurnal variation in winter is several times greater than the summer variation. These values are compared with the variation in f_0F2.

551.510.535:621.3.087.4 1563
Quality Control of Ionograms—A. C. Stanbury. (*J. Geophys. Res.*, vol. 67, pp. 413–414; January, 1962.) Description of an instrument for making quick, accurate checks of receiver and display characteristics.

551.510.535:621.391.812.63:551.594.5 1564
Some Observations of Ionospheric Absorption at Geomagnetic Conjugate Stations in the Auroral Zone—J. L. Hook. (*J. Geophys. Res.*, vol. 67, pp. 115–122; January, 1962.) The boundary of the polar cap absorption region appears to extend to the same effective magnetic latitude in the northern and southern hemispheres. During auroral events the absorption generally occurs simultaneously at the nearly magnetically conjugate stations of Farewell and Campbell Island.

551.510.535(086.4) 1565
World Maps of f_0E_s—S. Taguchi and H. Shibata. (*J. Radio Res. Labs., Japan*, vol. 8, pp. 355–386; September, 1961.) Contour maps based on local time and diurnal variation, showing the percentage of $f_0E_s > 5$ Mc have been constructed from ionospheric data obtained during 1958.

551.510.536 1566
The Electron Density Distribution above the F2 Peak and Associated Atmospheric Parameters—S. J. Bauer. (*J. Atmos. Sci.*, vol. 19, pp. 17–19; January, 1962.) Theoretical models of electron and ion distributions (O^+, H^+, He^+) are discussed.

551.510.536 1567
Upper-Atmosphere Helium Tons—W. B. Hanson. (*J. Geophys. Res.*, vol. 67, pp. 183–188; January 1962.) Available data are consistent with an atmospheric model in which a layer of helium ions at least 2000-km thick separates the ionosphere from the protonosphere.

551.510.536:551.594.6 1568
A Correction to the Exospheric Electron Density Estimate using the Nose Whistlers of March 19, 1959—J. H. Pope. (*J. Geophys. Res.*, vol. 67, p. 412; January, 1962.) A reinterpretation of the data gives electron densities about four times larger than those previously deduced [1519 of 1961 (Pope)].

551.594.5 1569
On the Orientation of Auroral Arcs—B. Hultqvist. (*J. Atmos. Terr. Phys.*, vol. 24, pp. 17–30; January, 1962.) The diurnal variation in the direction of quiet arcs at Kiruna is similar to the theoretical variation expected from Alfén's theory. The average arc direction near the auroral zone seems to be determined, for a given time, by projections of circles in the geomagnetic equatorial plane on to the earth's surface along the geomagnetic field lines.

551.594.5 1570
The Morphology of the Auroral Displays of 1957–1958: Part 1 & 2—T. N. Davis. (*J. Geophys. Res.*, vol. 67, pp. 59–110; January, 1962.) A study is made of all-sky camera records from a network of stations in Alaska and from an array of stations extending from subauroral latitudes to near the geomagnetic pole. The subjects considered include the time and latitude dependence of incidence, azimuthal alignment, direction of horizontal movement of auroral forms, and the relation of these subjects to magnetic disturbance.

551.594.5:539.16 1571
Argus Radar Returns in Conjugate Area—P. Newman. (*J. Geophys. Res.*, vol. 67, pp. 407–408; January, 1962.) The concept of orthogonal reflection from aurora and field-aligned ionization is used to explain the apparent movement of the radar returns.

551.594.5:550.385.4 1572
West-East Motion of an Auroral-Zone X-Ray Event—R. R. Brown. (*J. Geophys. Res.*, vol. 67, pp. 31–35; January, 1962.) A west-east motion of an auroral-zone X-ray event was observed late in the magnetic storm of June 22–23, 1961. Time delays between X-ray bursts at balloon altitude and increases in ionospheric absorption of cosmic radio noise indicate that velocity components along the auroral zone of 200–300 m/sec are present in this type of event.

551.594.6 1573
Midnight Fall in Atmospherics Activity on 27 Mc/s Band at Poona—M. W. Chiplonkar, R. N. Karekar, and P. R. Marwadi. (*J. Atmos. Terr. Phys.*, vol. 24, pp. 9–16; January, 1962.) On 70 per cent of nights there is a fall in activity which is explained in terms of a sudden decrease in the number of sources of atmospherics which occurs when the evening peak in thunderstorm activity crosses the West Coast of Africa. The fall is greater during magnetically disturbed periods.

551.594.6 1574
Dispersion of Whistlers—A. Kimpara. (*Nature*, vol. 193, February 17, 1962.) The whistler dispersion D is found to have diurnal and seasonal variations. The seasonal variation depends on geomagnetic latitude. Variations of D with geomagnetic and solar activity are also discussed.

551.594.6:523.745 1575
Whistlers and Solar Activity—A. Kimpara. (*Nature*, vol. 193, pp. 666–667; 1962.) A high negative correlation between whistler activity and sunspot number has been found for the years 1957–1960 in Japan.

551.594.6:523.78 1576
Recording of Electrical Signals of Particularly Low Frequency during the Solar Eclipse of 15th February 1961—H. L. König and E. Haine. (*Z. angew. Phys.*, vol. 13, pp. 478–480; October, 1961.) Recordings of atmospherics in the range 1–12 cps observed at Bonn and Munich at the time of the eclipse are reproduced. The characterisics immediately after the eclipse are similar to those normally obtained at sunrise. See also 889 of March (König, *et al.*).

551.594.6:550.385.4 1577
Variation of the Dispersion of Radio Whistlers during Magnetic Storms—Y. Corcuff. (*Ann. Géophys.*, vol. 17, pp. 374–377; October–December, 1961.) The whistler dispersion D_0 shows a special decrease at Poitiers 18–24 h after the commencement of an intense magnetic storm. The decrease is not observed for lesser storms. This is possibly due to the existence of favored paths which move to lower latitudes as the storm intensity increases.

551.594.6:551.510.536 1578
A Possibility of the Generation of V.L.F. Emissions in the Earth's Outer Exosphere—T. Ondoh. (*Planet-Space Sci.*, vol. 9, pp. 69–70; January/February, 1962.)

LOCATION AND AIDS TO NAVIGATION

621.396.663:621.396.677.6 1579
Bearing Errors dependent on Terrain and their Prevention in the Operation of V.H.F. Rotating Adcock Direction Finders PST 476 and 589—H. Kunze and H. Rattei. (*Telefunken Ztg.*, vol. 34, pp. 215–220; September, 1961. English summary, p. 278.) The results of practical trials are given and analyzed, and a table is included which lists the minimum distance from typical obstacles to obtain bearings of sufficient accuracy.

621.396.96 1580
Roughness and Radar Return—H. S. Hayre. (Proc. IRE, vol. 50, pp. 223–234; February, 1962.) Target terrain roughness should be described in terms of standard deviation and autocovariance of height rather than by qualitative adjectives.

621.396.962.3 1581
The Echo/Noise Ratio Obtainable in Radar by means of Pulse Compression—U. Tiberio. (*Alta Frequenza*, vol. 30, pp. 665–668; September, 1961.) Differences in the results achieved by methods of discontinuous or continuous pulse compression are discused. For English version see *Alta Frequenza*, vol. 30, pp. 840–845; December, 1961.

621.396.969 1582
Reducing Clutter in Air Route Surveillance Radar—W. W. Shrader. (*Electronics*, vol. 35, pp. 37–41; January 26, 1962.) Refinements to a long-range high-power system facilitate target interpretation under conditions of ground clutter, rain, and other unwanted signals.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 1583
Persistent International Polarization—J. R. Freeman, H. P. Kallmann, and M. Silver. (*Rev. Mod. Phys.*, vol. 33, pp. 553–573; October, 1961.) Persistent internal polarization effects in photoconductive materials are discussed from experimental and theoretical standpoints.

535.215:546.48'221 1584
The Influence of Hydrogen on the Photoconductivity of CdS Single Crystals—M. Asche and F. Eckart. (*Z. Phys.*, vol. 164, pp. 529–536; October 4, 1961.) See also 2239 of 1961.

535.215:546.48'221 1585
Influence of Heat Treatment upon Cadmium Sulphide Single Crystals—S. Kitamura. (*J. Phys. Soc. Japan*, vol. 16, pp. 2430–2439; December, 1961.)

535.215:546.48'221:621.382 1586
Cadmium Sulphide Crystals—D. A. Bell. (*Electronic Tech.*, vol. 39, pp. 94–97; March, 1962.) Some experiments in growing crystals suitable for use as a medium for the space-charge control of currents in a solid are described.

535.37:546.48'221 1587
Edge Edmission in CdS Crystals that Show Mechanically Excited Emission—C. W. Litton and D. C. Reynolds. (*Phys. Rev.*, vol. 125, pp. 516–523; January 15, 1962.)

537.226 1588
The Frequency Characteristics of Ceramic Dielectrics in the Range 10^2 to 5×10^9 c/s—W. Cirkler and W. Kuny. (*Frequenz*, vol. 15, pp. 277–286; September, 1961.) Methods of measurement are reviewed, and results ob-

tained for materials with low and high dielectric constant are analyzed. An equivalent circuit of a ceramic dielectric is derived.

537.227 1589
New Ferroelectrics of the Tetramethylammonium Trihalomercurate Family—E. Fatuzzo, R. Nitsche, H. Roetschi, and S. Zingg. (*Phys. Rev.*, vol. 125, pp. 514–516; January 15, 1962.)

537.227 1590
Some Experimental and Theoretical Studies of Ferroelectricity in $NaNO_2$—S. Nomura. (*J. Phys. Soc. Japan*, vol. 16, pp. 2440–2452; December, 1961.)

537.227 1591
Dielectric Behaviour of KNO_3 in its Ferroelectric Phase III—S. Sawada, S. Nomura, and Y. Asao. (*J. Phys. Soc. Japan*, vol. 16, pp. 2486–2494; December, 1961.)

537.227:546.431'824–31 1592
The Reproducibility of the Characteristics of Barium Titanate with respect to its Preparation—L. Walther and M. Mempel. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 195–197; October, 1961.) The effects of differences in the treatment of $BaTiO_3$ material during the manufacturing process are investigated.

537.228.1 1593
Approximate Method of Calculating Electromechanical Coupling Factor: Part 2—M. Marutake. (PROC. IRE, vol. 50, pp. 214–215; February, 1962.) A formula for the "longitudinal" piezoelectric effect is given, supplementing an analysis given earlier (2645 of 1961) for the "transverse" effect.

537.228.1 1594
Piezoelectric Properties of Triglycine Sulphate—T. Ikeda, Y. Tanaka and H. Toyoda. (*J. Phys. Soc. Japan*, vol. 16, pp. 2593–2594; December, 1961.)

537.228.1:534.232 1595
The Preparation of Piezoelectric Ceramic based on Lead Zirconate Titanate and its Application to Vibration Detectors—L. Walther and E. Richter. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 197–200; October, 1961.)

537.311.32:546.87:538.63 1596
New Phenomenon in Magnetoresistance of Bismuth at Low Temperature—L. Esaki. (*Phys. Rev. Lett.*, vol. 8, pp. 4–7; January 1, 1962.) Measurements at a magnetic field strength above several kilo-oersteds have shown a sharp change of slope in the I/V curve at a certain high electric field strength.

537.311.33 1597
New Semiconducting Compounds of Sulvanite Type—F. Hulliger. (*Helv. Phys. Acta*, vol. 34, pp. 379–382; August 15, 1961. In German.) Report of measurements on Cu_3VS_4 and related mixed crystals. For other new semiconductor compounds see 2656 of 1961 (Busch and Hulliger).

537.311.33 1598
Interband Transitions in Groups 4, 3–5, and 2–6 Semiconductors—H. Ehrenreich, H. R. Philipp, and J. C. Phillips. (*Phys. Rev. Lett.*, vol. 8, pp. 59–61; January 15, 1962.) New experimental data on the reflectance of Ge, InSb, InAs, GaAs and GaP are discussed in relation to band structure.

537.311.33:537.228.1 1599
Elastic Wave Propagation in Piezoelectric Semiconductors—A. R. Hutson and D. L. White. (*J. Appl. Phys.*, vol. 33, pp. 40–47; January, 1962.) Effects of interaction between piezoelectricity and semiconduction on acoustic wave propagation are discussed in terms of a one-dimensional model. Effects of drift, diffusion and trapping of carriers in an extrinsic semiconductor or photoconductor are considered and intrinsic semiconductors are discussed.

537.311.33:538.63 1600
The Influence of Inhomogeneities with Layer Structures on Galvanomagnetic Effects—G. Bogner and H. Rupprecht. (*Z. Naturforsch.*, vol. 16a, pp. 1152–1161; November, 1961.) The modification of magnetoresistance and Hall effects by structural inhomogeneities is investigated theoretically and by reference to experimental results obtained with InSb specimens. See also 4196 of 1961 (Rupprecht).

537.311.33:539.12.04 1601
Effects of Nuclear Radiation on Semiconductor Devices—M. Bertolotti. (*Alta Frequenza*, vol. 30, pp. 631–642 and pp. 862–872; September and December, 1961.) The types of damage are classified and the effects of various forms of radiation are reviewed. Over 120 references.

537.311.33:[546.28+546.289 1602
Ground-State Energies of Donors in Ge and Si—K. Narita and T. Shimizu. (*J. Phys. Soc. Japan*, vol. 16, p. 2588; December, 1961.) Calculations based on the effective-mass theory give a close approximation to experimental results for the energy level corresponding to the ground state. Results are tabulated for five impurity elements.

537.311.33:546.28 1603
The Composition of the Gold-Silicon Eutectic—E. G. Heath. (*J. Electronics and Control*, vol. 11, pp. 13–15; July, 1961.) A determination involving gravity segregation shows that the eutectic contains 3.15 ± 0.05 per cent Si by weight, or 18.6 per cent in terms of numbers of atoms.

537.311.33:546.28 1604
Direct Measurement of the Valley-Orbit Splitting of Shallow Donors in Silicon—T. G. Castner, Jr. (*Phys. Rev. Lett.*, vol. 8, pp. 13–15; January 1, 1962.) The valley-orbit splittings for P, As, Sb, and Bi donors in Si are determined by measuring the temperature dependence of the spin-lattice relaxation rate from 4.2–33°K.

537.311.33:546.28 1605
A.C. Field-Effect Measurements on Silicon—N. G. Einspruch. (*J. Electrochem. Soc.*, vol. 108, pp. 1164–1166; December, 1961.) Results are presented of AC field-effect measurements at 72°C on a CP-4-etched Si surface. A conductance minimum, necessary for interpreting the data in terms of the analysis of Kingston and Neustadter (3300 of 1955), is observed. The charge in the surface states is evaluated as a function of surface potential, and an equilibrium surface potential is calculated.

537.311.33:546.28 1606
Secondary Multiplication in Silicon—J. J. Moll and N. I. Meyer. (*Solid-State Electronics*, vol. 3, pp. 155–158; September, 1961.) An examination of the model used by Shockley (3028 of 1961) shows that the theoretical and experimental basis of some of the data should be reconsidered.

537.311.33:546.28:539.23 1607
The Preparation of Thin Silicon Single-Crystal Films by Cathode Sputtering—B. Hietel and K. Meyerhoff. (*Z. Phys.*, vol. 165, pp. 47–52; October 18, 1961.)

537.311.33:546.28:539.23 1608
Change of Absorption of Silicon Vapour-Deposited Films under the Influence of 75-keV Electrons—H. Hora. (*Naturwiss.*, vol. 48, p. 641; October, 1961.) Report on investigations of the dependence of the spectrum of optical transmissivity on bombardment energy.

537.311.33:546.281'26 1609
Traps in Grains of Silicon Carbide—R. Goffaux. (*Rev. gén. élect.*, vol. 70, pp. 615–623; December, 1961.) An extension of previous work (1218 of 1961) to an agglomeration of SiC grains of higher conductivity. Phenomena observed under AC excitation at normal and very low temperatures are interpreted in terms of Dropkin's model.

537.311.33:546.289 1610
Investigations of Self-Diffusion in Germanium—H. Widmer and G. R. Gunther-Mohr. (*Helv. Phys. Acta*, vol. 34, pp. 635–660; September 15, 1961. In German.) The rate of diffusion of radioactive Ge^{71} in Ge single crystals was measured by two different absorption techniques.

537.311.33:546.289 1611
Properties of Surface Imperfections Produced on Germanium by Cleaning Treatments—A. Kobayashi, K. Sugiyama, H. Arata, and Z. Oda. (*J. Phys. Soc. Japan*, vol. 16, pp. 2481–2486; December, 1961.) Effects of ion bombardment on the surface conductivity and Hall coefficient of Ge are examined for the temperature range 1.5–300°K.

537.311.33:546.289 1612
Theory of the Conductivity of High-Purity Germanium, at Very Low Temperatures, in the Pre-avalanche Region—A. Zylbersztejn. (*J. Electronics and Control*, vol. 10, pp. 429–436; June, 1961. In French.) At very low temperatures most of the charge carriers are trapped in the impurity centers. A theoretical explanation for the gradual increase in carrier density in the preavalanche region is given.

537.311.33:546.289 1613
Piezothermal Conductivity Effect in Germanium—R. W. Keyes and R. J. Sladek. (*Phys. Rev.* vol. 125 pp. 478–483; January 15, 1962.) The effect of static elastic strain on the thermal conductivity of Ge has been measured in the temperature range 1.5–4.2°K. See also 3453 of 1961 (Keyes).

537.311.33:546.289:538.569.4 1614
Theory of Cyclotron Resonance Absorption by Negative-Mass Holes in Germanium—R. C. Duncan, Jr., and B. Rosenblum. (*Phys. Rev.*, vol. 125, pp. 484–490; January 15, 1962.) "The effect of orbital quantization of cyclotron resonance absorption by negative-mass heavy holes in germanium is considered. The Landau level system for the heavy holes in the approximation of an axial energy surface is computed with an equation derived by Firsov. A semiclassical technique is used to compute the cyclotron absorption by the holes in negative mass states under thermal equilibrium conditions."

537.311.33:546.289:539.23 1615
***p*-Type Conductivity in Vapour-Deposited Germanium Films**—H. Pagnia. (*Z. Naturforsch.*, vol. 16a, pp. 1261–1262; November, 1961.) Report on measurements of conductivity and Hall effect on polycrystalline Ge films of thickness 400–2000 Å. Results show satisfactory qualitative agreement with values obtained for single-crystal *p*-type material. See also 3458 of 1961 (Eckart and Jungk).

537.311.33:546.48'241 1616
Elastic Moduli of Cadmium Telluride—

H. J. McSkimin and D. G. Thomas. (*J. Appl. Phys.*, vol. 33, pp. 56–59; January, 1962.)

537.311.33:546.681'19 1617
Vapour Growth of Gallium Arsenide—R. L. Newman and N. Goldsmith. (*J. Electrochem. Soc.*, vol. 108, pp. 1127–1130; December, 1961.) A method of growing epitaxial layers of GaAs on a GaAs substrate is described. Electrical properties of the junctions formed are noted.

537.311.33:546.681'19 1618
Vapour-Phase Growth of Gallium Arsenide Crystals—W. J. McAleer, H. R. Barkemeyer and P. I. Pollak. (*J. Electrochem. Soc.*, vol. 108, pp. 1168–1169; December, 1961.) A method is described for forming reproducible crystals of GaAs directly from the vapor phase.

537.311.33:546.681'19 1619
Epitaxial Vapour Growth of GaAs on Ge Single Crystals—T. Okada, T. Kano, and Y. Sasaki. (*J. Phys. Soc. Japan*, vol. 16, p. 2591; December, 1961.) GaAs single crystals are grown epitaxially on substrates of Ge single crystals in a closed quartz tube by the disproportionation reaction between GaAs and I_2.

537.311.33:546.681'86 1620
Evidence for a Selenium Donor Level Above the Principal Conduction Band Edge in GaSb—R. T. Bate. (*J. Appl. Phys.*, vol. 33, pp. 26–28; January, 1962.) Hall-coefficient and resistivity data on Se-doped GaSb at 77°K are shown to be consistent with an Se donor level 0.07 ev above the principal conduction band edge.

537.311.33:546.682'86 1621
The Infrared Absorption of Free Charge Carriers for Nonparabolic Band Structure using InSb as Example—F. R. Kessler and E. Sutter. (*Z. Naturforsch.*, vol. 16a, pp. 1173–1179; November, 1961.) Theoretical conclusions are confirmed by results of absorption measurements on 16 different specimens of *n*-type InSb.

537.311.33:546.682'86 1622
The Diffusion of Zinc and Cadmium in Indium Antimonide—R. B. Wilson and E. L. Heasell. (*Proc. Phys. Soc.*, vol. 79, pp. 403–408; February 1, 1962.) The results indicate surface-rate limitation; also a rapid out-diffusion of Se in Se-doped crystals.

537.311.33:546.682'86 1623
Plastic Bending of InSb—J. J. Duga. (*J. Appl. Phys.*, vol. 33, pp. 169–177; January, 1962.) Report on an experimental investigation of the effects of plastic bending on the electrical properties of *n*-type InSb.

537.311.33:546.682'86:535.215 1624
Large-Signal Photomagnetoelectric Effect—A. R. Beattie and R. W. Cunningham. (*Phys. Rev.*, vol. 125, pp. 533–540; January 15, 1962.) A large-signal theory is developed which is in good agreement with experimental results for *p*-type InSb at 80°K.

537.311.33:621.317.3 1625
Explicit Forms for the Conductivity and Permittivity of Bulk Semiconductors in Waveguides—K. S. Champlin and D. B. Armstrong. (Proc. IRE, vol. 50, p. 232; February, 1962.) Formulas are given for calculating the conductivity and permittivity of a semiconductor from microwave measurements on a sample filling a waveguide or on a thin sample in the center of a waveguide.

537.311.33:621.317.33 1626
Resistance Measurements in Semiconductor Techniques—Heywang and Zerbst. (See 1653.)

537.312.62 1627
Local Magnetic Moment Associated with an Iron Atom Dissolved in Various Transition-Metal Alloys—A. M. Clogston, B. T. Matthias, M. Peter, H. J. Williams, E. Corenzwit, and R. C. Sherwood. (*Phys. Rev.*, vol. 125, pp. 541–552; January 15, 1962.) Previous investigations [1244 of 1961 (Matthias, *et al.*)] are extended to cover nearly the whole of the second period of transition metals.

537.312.62:539.23:538.63 1628
Magnetic Shielding by Superconducting Films—R. J. Oakes. (*J. Appl. Phys.*, vol. 33, pp. 177–179; January, 1962.) "The magnetic field distribution and supercurrent density are calculated exactly by means of the Maxwell-London equations for the case of an ideal superconducting spherical shell immersed in a steady uniform magnetic field. It is shown that the magnetic field is strongly attenuated by the spherical shell even if the shell thickness is as small as 1000 Å."

538.221 1629
Experimental Determination of the Anisotropy Distribution in Ferromagnetic Powders—P. J. Flanders and S. Shtrikman. (*J. Appl. Phys.*, vol. 33, pp. 216–219; January, 1962.) A technique suitable for the determination of anisotropy distribution of a powder of uniaxial particles is developed; it can be applied for random or oriented particles.

538.221 1630
Demonstration of Magnetic Domains in Coarse- or Single-Crystal Specimens of the Alloy 50% Ni/50% Fe—C. Greiner. (*Naturwiss.*, vol. 48, pp. 617–618; October, 1961.) Discussion of Bitter patterns obtained after heat treatment.

538.221 1631
The Handling of Magnetic Materials—C. Heck. (*Radio Mentor*, vol. 27, pp. 868–874; October, 1961.) The adverse effects of incorrect mechanical or thermal treatment and of external magnetic fields on the characteristics of magnetic materials or components are discussed. 21 references.

538.221:538.652:534.232 1632
Investigations on Nickel and Nickel Alloys for Magnetrostrictive Transducers—O. Henkel. (*Hochfrequenz. und Elektroak.*, vol. 70, pp. 177–187; October, 1961.) Report on metallurgical tests and measurements of magnetic and mechanical characteristics.

538.221:539.23 1633
The Saturation Magnetization of Thin Films—W. Döring. (*Z. Naturforsch.*, vol. 16a, pp. 1146–1152; November, 1961.) Theoretical investigation of the dependence of saturation magnetization on film thickness and temperature.

538.221:539.23 1634
Vapour-Deposited Iron Films with Reproducible Optical Constants—G. Meyer. (*Naturwiss.*, vol. 48, p. 665; November, 1961.)

538.221:539.23 1635
Magnetic Properties of Electrolytically Produced Permalloy Films with Uniaxial Anisotrophy—A. Politycki. (*Z. angew. Phys.*, vol. 13, pp. 465–468; October, 1961.) Description of the method, and comparison of the characteristics of films prepared in this way with those reported by other authors.

538.221:621.318.134 1636
The Electrical Properties of Nickel Ferrites containing a Manganese Impurity—R. Parker and H. Lord. (*Proc. Phys. Soc. (London) A* vol. 79, pp. 383–388; February 1, 1962.) In certain composition ranges the easy conduction mechanism, involving ions of the same element in different valence states, is suppressed.

538.221:621.318.134 1637
Influence of Co^{2+} Ions on the Magnetic Anisotropy of Ferrimagnetic Oxides having Hexagonal Crystal Structures—F. K. Lotgering, U. Enz, and J. Smit. (*Philips Res. Repts.*, vol. 16, pp. 441–454; October, 1961.)

538.221:621.318.134:621.318.57 1638
The Behaviour of Ferrites with Rectangular Hysteresis Loop in Electrical Circuits—H. J. Kössler. (*Naturwiss.*, vol. 48, p. 618; October, 1961.) Formulas are derived for calculating the magnetizing current and dynamic losses of a ferrite core as a function of frequency.

539.23:621.3.032.27 1639
Techniques for Making Electrical Contacts to Thin Films—C. Feldman, H. E. Culver, and L. Davies. (*Rev. Sci. Instr.*, vol. 33, pp. 124–125; January, 1962.)

548.0 1640
A New Method of Zone Levelling for Materials having Distribution Coefficients in the Range of 0–0.6—I. Braun and E. Y. Wang. (*Solid-State Electronics*, vol. 3, pp. 79–90; September, 1961.) A uniform impurity-level distribution is obtained along a single crystal by doping a pure crystal at both ends and subsequently melting it repeatedly back and forth. Graphs are given for the effect of varying the individual parameters in the technique.

548.5 1641
A Revised Theory of the Floating-Crucible Technique of Crystal Growing—G. R. Blackwell. (*J. Electronics and Control*, vol. 10, pp. 459–463; June, 1961.) The optimum conditions for crystal growth are in practice very different from those predicted by the analysis of Airapetyants and Shmelev (2695 of 1961). The present analysis takes account of one term previously omitted.

548.5 1642
Constitutional Supercooling during Crystal Growth from Stirred Melts: Part 2—Experimental: Gallium-Doped Germanium—W. Bardsley, J. M. Callan, H. A. Chedzey, and D. T. J. Hurle. (*Solid-State Electronics*, vol. 3, pp. 142–154; September, 1961.) An experimental verification of the theory developed in Part 1 [1364 of April (Hurle)].

666.1.037.5:621.3.032.53 1643
Method of Making Glass-to-Metal Seals—S. J. Koch. (*Elektrotech. Z., Edn. B.*, vol. 13, pp. 695–696; December 25, 1961.) The advantages of the method described derive from the use of a Cr-oxide coating on the metal parts

MATHEMATICS

517 1644
Linear Randomly Varying Systems—G. Adomian. (Proc. IRE, vol. 50, pp. 203–204; February, 1962.) Comment on a theory of linear transformations or operators, in which the operator as well as the operand may be stochastic.

517.512.2 1645
The Delta Function and the Fourier Integral—J. L. Brown, Jr., L. Weiss, and A. W. Mcmurtrey. (Proc. IRE, vol. 50, pp. 217–219; comments on 635 of February with author's reply.

MEASUREMENTS AND TEST GEAR

621.3.018.41(083.74) 1646
Standard-Frequency Transmissions—J. M. Steele (*Wireless World*, vol. 68, pp. 160–165; April, 1962.) Description and tabulation of world-wide standard frequency and time-signal transmissions in allocated and additional bands at March, 1962.

621.3.018.41(083.74):621.375.9:538.569.4 1647
Double-Beam Masers as Primary Frequency Standards—J. De Prins, C. Menoud, and P. Kartaschoff. (*Helv. Phys. Acta*, vol. 34, pp. 428–432; August 15, 1961. In French.) Report of measurements on two types of $N^{15}H_3$ maser. See 1369 of April.

621.317.3:538.632 1648
Rotating-Sample Method for Measuring the Hall Mobility—F. M. Ryan. (*Rev. Sci. Instr.*, vol. 33, pp. 76–79; January, 1962.) By rotating the sample in a dc magnetic field, alternating-field Hall techniques may be used. The results of measurements made on a rotating sample are compared with values obtained by conventional techniques.

621.317.3:621.391.822 1649
Investigation of the Relation between Amplitude Distribution and Form Factor in Noise and for Time Functions—D. Pfefferkorn. (*Frequenz*, vol. 15, pp. 300–305; September, 1961.) The form factors of some periodic time functions and noise are calculated from statistical principles. Practical noise measurements are discussed, particularly those with instruments giving arithmetic mean values.

621.317.3:621.397.6 1650
The Accurate Measurements of Video Levels—Weaver. (See 1716.)

621.317.3:621.397.62 1651
Measurement Techniques for Television Receivers—Macek. (See 1719.)

621.317.329+621.317.42 1652
Determination of Electric and Magnetic Fields by means of Models—R. Otto. (*Frequenz*, vol. 15, pp. 309–315; October, 1961.) Methods outlined include the diaphragm type of mechanical model, the electrolyte tank, and resistance-network analogs.

621.317.33:537.311.33 1653
Resistance Measurement in Semiconductor Techniques—W. Heywang and M. Zerbst. (*Arch. tech. Messen*, no. 309, pp. 225–228; October, 1961.) Standard dc and high-frequency methods of measurement are reviewed.

621.317.36:621.317.755 1654
Cathode-Ray Frequency Meter and Signal Analyser—R. C. Cumming and L. D. Buchmiller. (PROC. IRE, vol. 50, pp. 221–222; February, 1962.) The transit-time effect on an electron deflection structure is used to give practically instantaneous measurement of frequency. A range of measurement of 200–500 Mc was achieved with 5-Mc resolution.

621.317.361.029.6:621.385.623 1655
Phase-Stabilized Klystron System and its Application to Microwave Spectroscopy and Microwave Frequency Standards—A. Narath and W. D. Gwinn. (*Rev. Sci. Instr.*, vol. 33, pp. 79–82; January, 1962.) A system is described for stabilizing the frequency and phase of a klystron where its frequency is to be varied continuously at any predetermined rate. The system also has application to superheterodyne detection systems in which the local oscillator is phase-locked to the signal klystron.

621.317.373 1656
The Measurement and Assessment of Phase Errors with the aid of Group Delay Data—H. Grosskopf. (*Nachrtech. Z.*, vol. 14, pp. 545–554; November, 1961.) The measurement of phase distortion, particularly in television transmission systems, is discussed. A quantitative assessment is possible on the basis of group delay measurements if these are carried out under the conditions defined.

621.317.382:538.63 1657
Magnetoresistance Multiplier with Higher Gain—S. Kataoka. (PROC. IRE, vol. 50, p. 216; February, 1962.) The magnetoresistance effect has several advantages over the Hall effect for use in power measurement, such as simple construction of the semiconductor element and much higher gain.

621.317.616 1658
The Measurement of Frequency Response with the Aid of the Cross-Correlation Function—G. Schweizer. (*Arch. elekt. Übertragung*, vol. 15, pp. 437–443; October, 1961.) In the methods discussed a sinusoidal or a stochastic input signal is used, and evaluation may be carried out by analog or digital means. The errors as a function of the duration of measurement are assessed.

621.317.74:621.372.8 1659
A Direct-Reading Waveguide Impedance and Reflection Indicator—J. K. Chamberlain and B. Easter. (*Electronic Eng.*, vol. 34, pp. 14–20; January, 1962.) A method is outlined for obtaining a CRT display of complex reflection coefficient derived from the outputs of three probes spaced along the waveguide. Details of equipment operating in the 5.9–7.0 Gc range are presented.

621.317.75:538.632 1660
Hall-Effect Stroboscope and Noise Discriminator—H. H. Wieder. (*Rev. Sci. Instr.*, vol. 33, pp. 64–70; January, 1962.) A sampling device incorporating a Hall-effect generator is described. Linearity is within 1 per cent in the range 100 cps–5 Mc.

621.317.794:621.316.86 1661
Carbon Resistor as a Bolometer for Low-Power R.F. Signals—B. Lalevic. (*Rev. Sci. Instr.*, vol. 33, pp. 103–105; January, 1962.) A carbon disk used as a bolometer at liquid-helium temperatures has a sensitivity of 10^{-10} w. Unusual characteristics observed in the temperature range between 2.05 and 1.5°K are explained by assuming a rectification process between the carbon and copper contacts.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

621.362:621.387 1662
Materials Problems in Cesium Thermionic Converters—L. Yang and F. D. Carpenter. (*J. Electrochem. Soc.*, vol. 8, pp. 1079–1086; November, 1961.) A brief description of converter design and consideration of component materials suitable for the extreme conditions under which they operate.

621.362:621.387 1663
Thermionic Current Transmission in a Strong Magnetic Field—A. Schock and C. L. Eisen. (*J. Appl. Phys.*, vol. 33, pp. 1–2; January, 1962.) An analytical proof that under certain conditions the fraction of emitted electrons reaching the collector equals the sine of the angle at which the magnetic field intersects the emitting surface. See 1009 of 1961 (Schock).

621.385.833 1664
The Practical Resolving Power of Electron Microscopes—W. E. Meyer. (*Optik*, vol. 18, no. 3, pp. 101–114; 1961.) Causes of image movement which impairs resolving power are surveyed, and means for avoiding such movement are discussed.

621.385.833 1665
A New Method for Increasing the Resolving Power of Electron Microscopes—W. Hoppe. (*Naturwiss.*, vol. 48, pp. 736–737; December, 1961.) The use of a diaphragm with circular rings is proposed to achieve phase coherence of the elementary waves.

621.385.833:621.397.331.22 1666
Field-Emission Microscopy at Low Current Densities with Image-Orthicon Image Intensifiers—M. Drechsler. (*Z. angew. Phys.*, vol. 13, pp. 445–450; October, 1961.) The improvements in image intensification which can be achieved with the aid of image orthicons with long storage time are summarized. Experimental results are discussed. Photographically reproducible images have been obtained for an emission current as low as 10^{-14} A.

621.398:616 1667
A New Intestinal Receiver—I. Raffel. (*Nachrtech.*, vol. 11, pp. 441–444; October, 1961.) Description of an improved version of the earlier design [(4364 of 1960 (von Ardenne, *et al.*)] and of measurement procedure.

621.56 1668
The Design Theory of Thermoelectric Cooling Elements and Units—J. E. Parrott and A. W. Penn. (*Solid-State Electronics*, vol. 3, pp. 91–99; September, 1961.)

PROPAGATION OF WAVES

621.391.812.6.029.45 1669
Very-Low-Frequency Electromagnetic Waves—R. N. Gould and W. R. Carter. (*Wireless World*, vol. 68, pp. 186–190; April, 1962.) A review of the characteristics of VLF propagation.

621.391.812.621 1670
The Application of Potential Refractive Index in Tropospheric Wave Propagation—R. G. Flavell and J. A. Lane. (*J. Atmos. Terr. Phys.*, vol. 24, pp. 47–56; January, 1962.) The concept of potential refractive index is discussed and the derivation of this parameter from radiosonde data. It is used to locate layer-type discontinuities in the troposphere and a correlation between these discontinuities and unusually high field strength in the frequency range 100–1000 Mc is established.

621.391.812.621.3 1671
Some Aspects of Anomalous Propagation at 3-cm Wavelength—D. B. Rai. (*J. Inst. Telecommun. Engrs., India*, vol. 7, pp. 177–180; July, 1961.) Some cases of superrefraction observed with 3-cm radars are analyzed. The formation of ducts, which can cause spurious echo heights, is attributed to small-scale features of the lower atmosphere.

621.391.812.624:621.396.67 1672
Experimental Aperture Medium Coupling Loss—Yeh. (See 1455.)

621.391.812.63:539.16 1673
Attenuation of Medium-Frequency Sky-Wave Signals in Australia following the Mid-Pacific High-Altitude Nuclear Explosions in August 1958—J. M. Dixon. (*J. Geophys. Res.*, vol. 67, pp. 123–125; January, 1962.) Evidence is presented to show that MF sky-wave propagation in Australia was influenced by the Johnston Island explosions. The effects extended from the second to the tenth day after each explosion.

621.391.812.63:551.510.535:523.75 1674
Ionospheric Effects Associated with the Solar Flare of September 28, 1961—K. Davies. (*Nature*, vol. 193, pp. 763–764; February 24, 1962.) Frequency variations of the order of several cycles per second were observed on standard-frequency transmissions received at Boulder, Colo., during a solar flare.

621.391.812.63.029.45 1675
Propagation of Very Low Frequencies in the Earth-Ionosphere System—R. Benoit and A. Houri. (*Ann. Géophys.*, vol. 17, pp. 370–373; October-December, 1961.) Evidence of cavity resonance effects in the earth-ionosphere system has been found. The resonant frequencies are 15, 21, 27, 34 and 40 cps. The apparatus was not suitable for observing the first-order mode at about 8 cps. A curve showing the distribution of energy in atmospheric noise from 11 cps to 8 kc is given. The presence of reflecting layers below 50 km is suggested.

621.391.812.63.029.45 1676
The Influence of the Earth's Magnetic Field on Radio Propagation by Waveguide Modes—K. G. Budden. (*Proc. Roy. Soc.* (*London*) *A*, vol. 265, pp. 538–553; February 6, 1962.) The waveguide theory of VLF propagation is extended to the case of an ionosphere not sharply bounded, taking into account the earth's curvature and magnetic field.

621.391.812.63.029.45 1677
The Ionosphere as a Whispering Gallery—K. G. Budden and H. G. Martin. (*Proc. Roy. Soc.* (*London*) *A*, vol. 265, pp. 554–569; February 6, 1962.) For some modes of the VLF earth-ionosphere waveguide the energy is concentrated near the base of the ionosphere, and the field strength near the ground is small. Such modes are analagous to the "whispering gallery" modes in sound wave propagation.

621.391.812.63.029.45 1678
Possible Propagation of Very-Low-Frequency Signals between Rugby and Rome through the Ionosphere—W. T. Blackband. (*Nature*, vol. 193, pp. 863–864; March 3, 1962.) Phase variations of the order of 600° in the GBR signal received at Rome were observed on a day when variations at Malta and Nairobi were less than 30° and 310°, respectively. Propagation via a meteor-ionization layer is suggested to explain this.

621.391.812.63.029.62 1679
Results of Long Experiments on Long-Distance (1100 km) Propagation in V.H.F. Bands—K. Tao, J. Asai, A. Sakurazawa, K. Sawaji, and M. Yamaoka. (*J. Radio Res. Labs., Japan*, vol. 8, pp. 331–353; September, 1961.) Experimental results for the period December, 1957–September, 1959 showing seasonal and diurnal changes in both ionospheric scatter and E_s-layer propagation are discussed.

621.391.812.631 1680
Effect of Radio Fade-Out in the F2 Layer—R. K. Suryanarayana. (*J. Atmos. Terr. Phys.*, vol. 24, pp. 57–64; January, 1962.) The hour-to-hour values of f_oF2 on the day of a fade-out are compared with the mean values on ten control days. During 1957–1959, f_oF2 tended to increase after a fade-out at geomagnetic latitudes of about 14° or less; it usually decreased at latitudes in the range 14°–35°.

RECEPTION

621.376.23:621.372.54 1681
Machines that Sort Signals from Noise—(*Engineering* (*London*), vol. 192, pp. 166–167; August 11, 1961.) An application of the adaptive nonlinear filter to the detection of very weak signals in noise. See also 1999 of 1961 (Jakowatz and White).

621.391.812 1682
The Field-Strength Distribution at the Edge of the Silent Zone—W. Dieminger and G. Rose. (*Nachrtech. Z.*, vol. 14, pp. 492–495; October, 1961.) The results of field-strength measurements at 8.1 and 18.3 Mc over the 2000-km path Sodankylä (Finland)–Lindau (Germany) are analyzed in relation to the relevant MUF data. Ionospheric focusing and ground backscatter effects are discussed.

621.391.812.62:621.396.666 1683
Diversity Effects in Spaced-Antenna Reception of Tropospheric Scatter Waves—M. Hirai. (*J. Radio Res. Labs., Japan*, vol. 8, pp. 301–329; September, 1961.) Theoretical expressions are developed for the amplitude correlation between signals received at antennas spaced horizontally and vertically, and a comparison of calculated and measured values is given.

621.391.822 1684
The Distribution Curves of the Times during which an Arbitrarily Specified Value is Exceeded in the Case of White Noise—H. Zuhrt. (*Arch. elekt. Übertragung*, vol. 15, pp. 415–422; September, 1961.) For white noise of a given bandwidth the statistical distribution of the duration of excess noise current is calculated for various bandwidths and limits. Measurement results are in close agreement with computed curves.

621.391.823:551.510.535:621.3.087.4 1685
The Reduction of Local Radio Interference caused by H.F. Ionospheric Sounding Equipment—V. A. W. Harrison. (*J. Brit. IRE*, vol. 23, pp. 145–149; February, 1962.) The use of short bursts of pulses instead of continuous transmissions has virtually eliminated interference caused during absorption measurements and the use of horizontal terminated folded dipoles, with other precautions, has minimized interference during vertical-incidence soundings.

621.391.827.25:621.396.621.53 1686
Self-Heterodyning and Ambiguity in Mixing Processes—W. Hasselbeck. *Telefunken Ztg.*, vol. 34, pp. 231–239; September, 1961. English summary, p. 279.) The difficulties arising in superheterodyne reception due to second-channel interference and associated effects are discussed. Design rules are given for avoiding such effects in receivers with local-oscillator frequency higher or lower than the received signal frequency.

621.396.62:621.382.23 1687
Results obtained with Tunnel-Diode Superregenerative Receivers—C. A. Skalski and T. P. Kabaservice. (PROC. IRE, vol. 50, pp. 215 216; February, 1962.) Test results, quench and signal waveforms are given for receivers operating at 100, 325, and 930 Mc.

621.396.62:621.391.883 1688
A Completely Consistent Definition of Temperature Sensitivity including Negative-Conductance Devices—S. T. Fisher. (PROC. IRE, vol. 50, p. 204; February, 1962.) The "temperature sensitivity" or system noise temperature of a receiver is a more useful measure of receiver sensitivity than the noise figure.

621.396.625.1:621.391.83 1689
The Measurement of the Distortion-Limited 'Maximum Usabl Sensitivity' of Radiotelegraphy Receivers—E. von Jasienicki, W. Kronjäger, and K. Vogt. (*Nachrtech. Z.*, vol. 14, pp. 477–480; October, 1961.) Discussion of the results of measurements in line with CCIR recommendations.

621.396.666:621.385.5.032.265 1690
Telemetry Diversity Combiner uses Beam-Deflection Technique—V. A. Ratner. (*Electronics* vol. 35, pp. 42–43; February 2, 1962.) The circuit has five tubes of which two are of the beam-deflection type. It responds to fading rates of several kilocycles per second and has a bandwidth variable from a few cycles per second to several megacycles per second.

621.396.722 1691
The Wittsmoor Measuring and Receiving Station of Norddeutscher Rundfunk: Collaboration at Home and Abroad—R. Dobiasch and H. Ehlers. (*Rundfunktech. Mitt.*, vol. 5, pp. 249–258; October, 1961.) Continuation of 675 of February (Ehlers and Thies) dealing with the tasks of the station particularly with regard to signal-strength measurements for common-frequency transmitters and ionospheric investigations under the auspices of the EBU.

621.396.722:621.398 1692
Remote Control of Receivers—K. Fischer, F. Laubach, and R. Zimmermann. (*Telefunken Ztg.*, vol. 34, pp. 240–248; September, 1961. English summary, p. 279.) The operation of radio receiving stations in isolated areas free from interference is considered, and details are given of equipment for the remote control and supervision of receivers.

STATIONS AND COMMUNICATION SYSTEMS

621.376.3.4 1693
Angle-Modulated Waves—A. Bredekamp. (*Electronic Tech.*, vol. 39, pp. 116–117; March, 1962.) The lowest-frequency power fluctuations of the modulated wave are distinguished from the average power during a modulation period and the effect of the phase relation between carrier and modulating wave is evaluated. See 4293 of 1961 (Medhurst).

621.391 1694
Truncation Error of Sampling-Theorem Expansions—H. D. Helms and J. B. Thomas. (PROC. IRE, vol. 50, pp. 179–184; February, 1962.) An investigation is made into the "truncation error" which arises when reconstituting a bandlimited function over only a finite number of samples of this function in an appropriate sampling-theorem expansion.

621.391 1695
The Problem of Error Propagation and Reliability in Signal Transmission using Electronic Analogue Computers for Reverse Calculation—K. Löhn, H. Weinerth, and H. Wolter (*Arch. elekt. Übertragung*, vol. 15, pp. 455–466; October, 1961.) The system error and noise characteristics of signal transmission using the computer method proposed, *e.g.*, in 3852 of 1959 (Wolter) are investigated theoretically and confirmed experimentally.

621.391:621.376.56 1696
Comparison of the Conventional with the Reflected Binary Code in Signal Transmission by Pulse Code Modulation—R. Kersten. (*Frequenz*, vol. 15, pp. 316–323; October, 1961.)

621.391.63 1697
Eighty Years of Photophones—C. M. Cade. (*Brit. Commun. Electronics*, vol. 9, pp. 112–115; February, 1962.) A brief history of devices for communication by means of light beams, a note on present-day applications.

621.396.523.1 1698
Radio Signals from Other Planets—R. N. Bracewell. (PROC. IRE, vol. 50, p. 214; February, 1962.) Comment on a note by Golay (vol. 49, p. 959; May, 1961). See also 2900 of 1960.

621.396.65 1699
The Number of Possible Paths in Radio Links using the 7-Gc/s Miniature Radio-Link Equipment—R. Schienemann. (*Telefunken Ztg.*, vol. 34, pp. 221–231; September, 1961. English summary, p. 278.) Calculations are made of the type and magnitude of the interference which arises in a given area with common-frequency operation particularly when using six-channel equipment of the type described in 330 of 1961. Allocation plans are considered and the maximum number of paths is estimated for various allocation conditions.

621.396.71 1700
The V.L.F. Station at Anthorn—(*Brit. Commun. Electronics*, vol. 9, p. 119; February, 1961.) A short description of the station to be built near Carlisle, Cumberland. It will operate on frequencies of 16–20 kc with two 400-kw transmitters.

621.396.712.3:697.9 1701
The Air-Conditioning Plant of the Broadcasting House, Paris—B. Mantran. (*Rundfunktech. Mitt.*, vol. 5, pp. 209–213; October, 1961.) The installation described is fully automatic. For English version see *E.B.U. Rev.*, no. 68A, pp. 134–137; August, 1961.)

621.396.74 1702
Broadcasting and Radio Transmitters—P. J. Noizeux. (*Rev. telegr., electrónica, Buenos Aires*, vol. 50, pp. 862–866; November, 1961.) The possibility of setting up a network of local 250-w medium-wave transmitters in the Argentine is considered with reference to propagation and soil-conductivity data and to results obtained in the U.S.A.

621.396.91(204) 1703
Communications and Electronics in the I.C.A.O. Weather Ships—P. Oomen. (*Brit. Commun. Electronics*, vol. 9, pp. 94–99; February, 1962.) Equipment used for communication, navigation and upper-air observation is described.

621.396.97:534.76 1704
A Pulse Time Multiplex System for Stereophonic Broadcasting—G. D. Browne. (*J. Brit. IRE*, vol. 23, pp. 129–137; February, 1962.) A system for VHF broadcasting of stereophonic sound by means of time division multiplex is described. The possibility of adding a third channel is briefly discussed. Encoding, decoding and synchronizing arrangements are shown and results of preliminary measurements are presented.

SUBSIDIARY APPARATUS

621.3.087.4:621.395.625.3:621.317.42 1705
Investigation of the Magnetic Recording Process with Step Functions—Teer. (See 1447.)

621.311.62:621.314.6:621.397.62 1706
H. T. Supply Units for Television Receivers Equipped with Silicon Diodes—J. F. van Dam, L. A. L. Esseling, A. M. H. Schellekins, and A. P. Tanis. (*Electronic Applic.*, vol. 21, pp. 1–24; May, 1961.) A short survey of semiconductor rectifiers is given and design parameters for rectifier circuits and *RC* smoothing networks are discussed.

621.311.69:621.383.5 1707
An Explanation of the Superior Radiation Resistance of *p*-Type Base Si Solar Cells—R. V. Babcock. (*J. Electrochem. Soc.*, vol. 108, pp. 1119–1122; December, 1961.) Calculation of the effect of electron flux on the minority-carrier lifetime in the base region gives results which agree well with measurements of actual damage.

621.314.63 1708
Current-Limited Rectifiers—G. F. Montgomery. (PROC. IRE, vol. 50, pp. 190–193; February, 1962.) A description is given of a class of rectifier circuits that limit their output current to a specified maximum. Applications are suggested.

621.362:621.314.5 1709
Heating to A.C. Conversion using Thermoelectric Generators and Tunnel Diodes—F. G. Gevert, S. Wang, and R. U. Broze. (*Solid-State Electronics*, vol. 3, pp. 100–104; September, 1961.) Single-cell PbTe generators operating between 600° and 50° C produce 1 w of electric power. The dc output of 120 mv at 8A is converted to high-voltage power by using a high-current tunnel diode as a dc/ac converter.

TELEVISION AND PHOTOTELEGRAPHY

621.397.13:612.84 1710
The Effect of Room Illumination on Visual Comfort in Television—H. Grosskopf. (*Rundfunktech. Mitt.*, vol. 5, pp. 244–248; October, 1961.) Optimum viewing conditions are defined with regard to picture dazzle which can be controlled by the illumination of the picture surround.

621.397.13:621.372 1711
Noise and Intermodulation Problems in Multichannel Closed-Circuit Television Systems—C. A. Collins and A. D. Williams. (*Commun. and Electronics*, no. 57, pp. 486–491; November, 1961.) A discussion of the problems of thermal noise and intermodulation products due to amplifier nonlinearity.

621.397.132 1712
Progress in SECAM Colour Television—H. Peyroles. (*Radio Mentor*, vol. 27, pp. 862–863; October, 1961.) Brief outline of the principles and advantages of the system.

621.397.331.24 1713
Theory of a High-Slope Television Picture Tube with a Negative Parallel Wire Control Grid immediately in Front of the Cathode—E. Gundert and H. Lotsch. (*Telefunken-Röhre*, no. 40, pp. 5–42; October, 1961.) Theoretical treatment of the tube described in 2789 of 1961. Experimental results are discussed in respect of the maximum slope achievable.

621.397.331.24:621.317.39 1714
Geometric Measurements on the Screen of Television Picture Tubes—G. Heller. (*Radio Mentor*, vol. 27, pp. 876–877; October, 1961.) The geometry and linearity of the tube image can be measured with the aid of a line raster optically projected on to the front of the tube screen.

621.397.334 1715
Problems of Photoelectronics of Colour-Television Flying-Spot Scanners for Films and Transparencies—M. Samlenski. (*Nachrtech.*, vol. 11, pp. 393–396; September, 1961.) Methods of improving SNR in the various elements of a flying-spot scanning system (*e.g.*, 2390 of 1961) are discussed.

621.397.6:621.317.3 1716
The Accurate Measurement of Video Levels—L. E. Weaver. (*E.B.U. Rev.*, no. 69A, pp. 195–197; 1961.) The method described allows levels to be set to an absolute accuracy within about ±0.1 db under operational conditions. See also 3166 of 1961. For German version see *Rundfunktech. Mitt.*, vol. 5, pp. 261–263; December, 1961.)

621.397.61.029.6 1717
Problems of U.H.F. Television Transmitter Technique—T. M. J. Jaskolski. (*Rundfunktech. Mitt.*, vol. 5, pp. 214–230; October, 1961.) Extended version of 2790 of 1961.

621.397.61.029.6 1718
U.H.F. Television Transmitters using Tetrodes—A. Simon and S. Tobies. (*Rundfunktech. Mitt.*, vol. 5, pp. 231–239; October, 1961.) Circuit and constructional details are given of band IV/V transmitters incorporating recently developed types of tetrode [4439 of 1960 (Kleen)]. See also 1660 of 1961 (Finkbein, *et al.*).

621.397.62:621.317.3 1719
Measurement Techniques for Television Receivers—O. Macek (*Arch. tech. Messen*, nos. 309 and 312, pp. 229–232 and pp. 11–14; October, 1961 and January, 1962.) Survey of modern methods covering the IEC recommendations and measurement of picture quality, sensitivity to signal and interference, stability, and other characteristics. 76 references.

621.397.63:621.395.625.3 1720
A Frequency-Changing Modulator-Demodulator using V.H.F./F.M. Technique for Television Tape-Recording Equipment—H. Fix and W. Habermann. (*E.B.U. Rev.*, no. 68A, pp. 146–154; August, 1961.) English version of 3172 of 1961.

621.397.74 1721
The Television Circuit between France and North Africa—F. Anguéra. (*E.B.U. Rev.*, no. 69A, pp. 182–189; October, 1961.) Description of the 4-Gc radio link between France and Algiers with a relay station on Majorca. Test results are given and operational plans are discussed.

621.397.74 1722
The Equipment used on the France-North Africa Television Circuit—J. D. Koenig. (*E.B.U. Rev.*, no. 69A, pp. 190–194; 1961.) Description of the 4-Gc FM transmitter and space-diversity receiving equipment used for the France-Algiers radio link (1721) above.

TRANSMISSION

621.396.74 1723
Decoupling Bridge Circuits for Parallel Connection of Transmitters in the Short-Wave and V.H.F. Bands: Part 1—W. Buschbeck. (*Nachrtech. Z.*, vol. 14, pp. 567–575; November, 1961.) The characteristics of a number of bridge circuits are reviewed, particularly with regard to bandwidth and performance under mismatch conitions.

TUBES AND THERMIONICS

621.382:621.372.32 1724
Semiconductor Analogue of a Cold-Cathode Counter Tube—A. Ambroziak. (*Electronics*, vol. 35, pp. 46–47; February 9, 1962.) The operation of a decade-counting solid-state device, the Semidectron, which can be triggered by either positive- or negative-going pulses, is described. The output of a practical five-step counter is illustrated.

621.382:621.375.9 1725
Transferred-Electron Amplifiers and Oscillators—C. Hilsum. (PROC. IRE, vol. 50, pp. 185–189; February, 1962.) GaSb and semi-insulating GaAs should both display negative resistances due to the conduction band system

having two minima, the lower minimum having a smaller electron effective mass.

621.382:621.375.9 1726
The Dielectric Triode: a Low-Noise Solid-State Amplifier—P. W. Webb and G. T. Wright. (*J. Brit. IRE*, vol. 23, pp. 111–112; February, 1962.) Current fluctuations in the space-charge-limited dielectric triode [3297 of 1960 (Wright)] are discussed. The noise power level in this device is considerably less than in the space-charge-limited vacuum triode or in the diffusion-limited transistor.

621.382.2+621.382.3 1727
Recent Developments in the Field of Crystal Diodes and Transistors—F. W. Dehmelt. (*Telefunken-Röhre*, no. 40, pp. 43–72; October, 1961.) Four new types of semiconductor device are described and their applications are discussed: a) the parametric diode, b) the tunnel diode, c) the tunnel transistor, and d) the *p-n-p-n* diode.

621.382.22 1728
An Anomalous Effect in the Characteristics of GaP Point-Contact Diodes—A. Epstein and J. Caldwell. (PROC. IRE, vol. 50, pp. 209–210; February, 1962.) A hysteresis effect observed in the *I/V* characteristics of *n*-type GaP is attributed to the formation of trapping centers in the space-charge region.

621.382.23 1729
Nature of the Valley Current in Tunnel Diodes—T. P. Brody. (*J. Appl. Phys.*, vol. 33, pp. 100–111; January, 1962) "An explanation of the excess current up to and including the valley point, observed in tunnel diodes, is suggested in terms of tunnelling between impurity band states of the heavily doped *p* and *n* regions. Density-of-states curves are constructed, based on several different models of impurity bands, and the tunnelling current between such bands is computed and compared with experiment."

621.382.23 1730
Approximation of Tunnel-Diode Characteristics—K. Tarnay. (PROC. IRE, vol. 50, pp. 202–203; February, 1962.) The approximation is based on the currents and voltages corresponding to the peak and valley points of the characteristics.

621.382.23 1731
Peak Current Behaviour in Ge Esaki Junctions—H. F. Lockwood. (*J. Appl. Phys.*, vol. 33, pp. 245–246; January, 1962.) A discussion of the deterioration of the *I-V* characteristic observed during operation of a Ge junction. Changes in the peak/valley current ratio with decreasing peak current density and the variation of I_p/C with increasing junction width are illustrated.

621.382.23 1732
The Characteristics of some Germanium Tunnel Diodes—B. Mroseiwicz and E. Heasell. (*J. Electronics and Control*, vol. 10, pp. 405–428; June, 1961.) The procedures used to make tunnel diodes are described. Details of junction structure may play an important role in determining behavior.

621.382.23 1733
Remarks on the Determination of the Lead Impedance of Tunnel Diodes—E. Baldinger and U. Spycher. (*Helv. Phys. Acta*, vol. 34, pp. 420–425; August 15, 1961. In German.) Lead impedance is evaluated from measurements of the frequency dependence of the diode impedance, which is governed by the skin effect.

621.382.23 1734
On the Impurity Concentration of the *p*-Type Recrystallized Layer of Tunnel Diode—M. Shoji. (*J. Phys. Soc. Japan*, vol. 16, p. 2596; December, 1961.) A method of determining the carrier concentration of the recrystallized region is described. It is based on an analysis of the dependence of the tunnel current on the Ga concentration in the alloy metal which was used to form the tunnel junction.

621.382.23:621.318.57 1735
Designing Tunnel-Diode Circuits using Composite Characteristics—Rabinovici and Klapper. (See 1469.)

621.382.23:621.375.9 1736
The Tunnel-Diode Superregenerative Amplifier—Jordan and Elco (See 1497).

621.382.233:621.318.57 1737
Compound *p-n-p-n-p* Switches for Bi-directional-Bistable Electronic Switches—K. Yamagishi. (*Rev. Elec. Commun. Lab., Japan*, vol. 9, pp. 545–551; September/October, 1961.) The characteristics of the compound *p-n-p-n-p* diode are examined and methods of controlling it are considered.

621.382.3:621.391.822 1738
Measurement Problems in Noise Investigations on Transistors—R. Köstner. (*Nachrtech.*, vol. 11, pp. 457–461; October, 1961.) Review of noise-measurement methods and discussion of ways of minimizing measurement errors.

621.382.3.049.7 1739
Moisture Exclusion from Encapsulation of Long-Life Transistors—R. I. B. Cooper. (PROC. IRE., vol. 50, pp. 141–147; February, 1962.) Methods are considered for excluding moisture from long-life transistor capsules during manufacture and subsequently.

621.382.323:621.372.44 1740
Field-Effect Transistor as a Negative-Resistance Device—T. Niimi and T. Hayashi. (*Electronics*, vol. 35, pp. 48–49; February 2, 1962.) The significance of the mechanical configuration of the device with regard to its negative-resistance characteristics is discussed.

621.382.333 1741
Minority-Carrier Lifetime in the Base Region of Transistors—F. J. Hyde and H. J. Roberts. (*J. Electronics and Control*, vol. 11, pp. 35–45; July, 1961.) The recombination of holes on the surface of the base of *p-n-p* transistors increases bulk recombination. A model leads to the conclusion that the effective lifetime should now be less than half the bulk lifetime. Lifetime measurements and theory are discussed.

621.382.333 1742
Beta Cut-Off Frequencies of Junction Transistors—J. Lindmayer and C. Y. Wrigley. (PROC. IRE, vol. 50, pp. 194–198; February, 1962.) Calculations are made of the 3-db cutoff frequency and gain bandwidth product for the common-emitter current gain. The results are applicable to all transistors.

621.382.333 1743
High-Frequency Available Power Gain of Diffused-Base Transistors—N. Kozuma and I. Miwa. (PROC. IRE, vol. 50, pp. 199–200; February, 1962.) Expressions are given for the power gain of transistors having a drifting field in the base region, used in the common-emitter configuration.

621.382.333 1744
Base-Region Transport Characteristics of a Diffused Transistor—D. P. Kennedy and P. C. Murley. (*J. Appl. Phys.*, vol. 33, pp. 120–125; January, 1962.) A one-dimensional analysis is given of the minority characteristics of a transistor base region containing an arbitrary drift field distribution. The analysis is applied to the determination of the base-region transport efficiency for diffused transistors.

621.382.333:621.317.3 1745
Transistor Base Resistance—L. van Biljon. (*Electronic Tech.*, vol. 39, pp. 108–115; March, 1962.) Methods of measurement for the normal and inverse transistor are investigated and compared experimentally. The influence of collector current and collector-base voltage on the base resistance is determined.

621.382.333:621.318.57:681.142 1746
kMc/s Planar Transistors in Microwatt Logic Circuitry—Allison, Beeson, and Schultz. (See 1462.)

621.382.333.015.5 1747
Voltage Breakdown of Transistors—F. G. Heymann and L. van Biljon. (*Electronic Tech.*, vol. 39, pp. 117–118; March, 1962.) Comment on 4350 of 1961 (Ryder-Smith).

621.382.333.32 1748
Theory and Experimental Characteristics of a Tunnel Triode—W. Fulop and S. Amer. (*J. Brit. IRE*, vol. 23, pp. 113–120; February, 1962.) The performance of the device was evaluated with the aid of a computer for a number of geometries, integrating across the junction face. The characteristics obtained showed good agreement with those measured. Multivalued current-voltage operation is considered for two configurations.

621.382.333.34 1749
Turn-Off Gain in *p-n-p-n* Triodes—J. M. Goldey, I. M. Mackintosh, and I. M. Ross. (*Solid-State Electronics*, vol. 3, pp. 119–122; September, 1961.) The mechanism of base-current turn-off is discussed and a method of obtaining large turn-off gain is demonstrated.

621.383.29 1750
High-Gain Dynamic Microwave Photomultiplier—O. L. Gaddy and D. F. Holshouser. (PROC. IRE, vol. 50, pp. 207–208; February, 1962.) Description of an experimental photomultiplier whose operation is based on the action of a microwave electric field and a crossed steady magnetic field. The system appears promising as a low-level, low-noise detector of high-frequency modulated light.

621.383.5 1751
A Negative-Resistance Photoelectric Diode—W. Rindner. (*Solid-State Electronics*, vol. 3, pp. 123–126; September, 1961.) The construction and some of the properties of a Si photocell displaying a negative-resistance region in its *I/V* characterisic are described.

621.383.5 1752
Transient Photovoltaic Response of Diffused-Junction Silicon Photodiodes—T. E. Hartman. (*Solid-State Electronics*, vol. 3, pp. 127–133; September, 1961.) A transient equivalent circuit is proposed and compared with experimental observations over a wide range of operating conditions.

621.383.52 1753
Photoeffects in Silicon Surface-Barrier Diodes—A. J. Tuzzolino, E. L. Hubbard, M. A. Perkins, and C. Y. Fan. (*J. Appl. Phys.*, vol. 33, pp. 148–155; January, 1962.) The operating characteristics of the device used as a photodiode are described.

621.385.004.6 1754
Means of Increasing the Reliability of Thermionic Valves—H. J. Schütze and F. Dlouhy. (*Telefunken-Röhre*, no. 40, pp. 169–186; October, 1961.) Discussion of material characteristics and manufacturing techniques

likely to affect valve reliability. The value of measurements at all stages of manufacture is emphasized. 39 references.

621.385.032.213.23 1755
Evaporation from Barium Nickel Matrix Cathodes—R. O. Jenkins and W. G. Trodden. (*J. Electronics and Control*, vol. 11, pp. 1–12; July, 1961.) In early life the evaporant is mainly free Ba but later it consists of BaO and Ni in comparable amounts. The evaporation energy increases with time from about 2.5 to 4.0 ev. The rates of evaporation are also discussed.

621.385.032.213.23 1756
New Developments in Oxide-Coated Cathodes—(*Philips Tech. Rev.*, vol. 23, pp. 19–27; October 16, 1961.)

Part 1: Oxide-Coated Cathodes for Loads of 1–2 A/cm²—H. J. Lemmens and P. Zalm.

Part 2: An Oxide-Coated Cathode with a Half-Watt Heater for Cathode-Ray Tubes—F. H. R. Almer and A. Kuiper.

621.385.032.269.1 1757
Analysis of Spot Size Formation in Bipotential Electron Guns—A. Sandor. (*J. Electronics and Control*, vol. 10, pp. 245–260; April, 1961.) "A semi-empirical method is worked out which permits prediction of the final spot size on the viewing screen of triode-type electron guns with conventional grid aperture sizes of 0.025–0.035 in. diameter."

621.385.2+621.387 1758
Space-Charge Instabilities in Electron Diodes and Plasma Converters—C. K. Birdsall and W. B. Bridges. (*J. Appl. Phys.*, vol. 32, pp. 2611–2618; December, 1961.) Reviews of classical static solution and presents briefly new transient solutions for space-charge instabilities.

621.385.3 1759
Current Decay of Millisecond Duration in Thermionic Valves (the Grid-Film Effect)—J. Seymour. (*Brit. J. Appl. Phys.*, vol. 13, pp. 9–16; January, 1962.) A film of Ba and Sr oxides on the control grid, caused by cathode evaporation during processing, behaves as a parallel *RC* combination in series with the grid.

621.385.6 1760
Stiffness of Electron Beams—J. L. Palmer and C. Süsskind. (*J. Electronics and Control*, vol. 10, pp. 365–373; May, 1961.) Stiffness is defined as the rate of change of force, in the direction transverse to the beam, that acts to restore a displaced electron to its equilibrium trajectory in a laminar beam. The new parameter is discussed in relation to different types of flow.

621.385.6 1761
Relativistic Beam-Wave Interactions—J. E. Rowe.—(Proc. IRE, vol. 50, pp. 170–178; February, 1962.) The effects of relativistic mass changes of electrons taking part in nonlinear interactions in linear beam devices are described and the theory is applied to the klystron.

621.385.6 1762
Llewellyn-Peterson Equations for Crossed-Field Beams—J. F. Rando. (Proc. IRE, vol. 50, p. 206; February, 1962.) The method used for the derivation of the equations eliminates singularities found in the transformation given by Van Duzer (IRE Trans. on Electron Devices, vol. ED-8, pp. 78–86; January, 1961.)

621.385.6 1763
Permanent-Magnet Focusing Systems for U.H.F. Valves—P. Meyerer. (*Arch. elekt. Übertragung*, vol. 15, pp. 467–474; October, 1961). Design problems regarding the magnet system for velocity-control tubes are discussed which can be solved with the aid of electrolyte-tank analog methods. Practical design details described cover the magnet system for a 4-Gc traveling-wave tube and a mm-λ backward-wave oscillator, and periodic structures for electron-beam focusing.

621.385.6:621.375.9:621.372.44 1764
A Note on the Pump Electrodes of the Quadripole Amplifier—H. W. Tuffill and M. A. Wharmby. (*J. Electronics and Control*, vol. 11, pp. 47–51; July, 1961.) The required hyperbolic potential distribution in the space occupied by the beam can be produced by four cylindrical poles.

621.385.6:621.375.9:621.372.44 1765
On Cyclotron-Wave Noise Reduction—P. A. H. Hart. (Proc. IRE, vol. 50, pp. 227–228; February, 1962.) The fast-wave noise power in a beam from a Brillouin gun may be reduced sufficiently for use in an Adler tube.

621.385.6.029.65 1766
A Note on Impedance and Saturation Power of a Multiple Ladder Array at Millimetre Wavelengths—E. A. Ash. (*J. Electronics and Control*, vol. 10, pp. 39–43; January, 1961.) The gain and saturation output power per ladder in a multiple ladder array is greater than that for a single ladder. Theoretical results from work on millimeter-wave tubes show that the maximum factor by which the interaction impedance can be increased is 2, and the maximum increase of saturation power of the order of 3.4.

621.385.6.032.269.1:621.375.9 1767
Parametric - Amplifier Electron Gun—P. A. H. Hart and C. Weber. (*Philips Res. Repts.*, vol. 16, pp. 376–388; August, 1961.) Two guns of high perveance (3×10^{-6} $AV^{-3/2}$) and low beam voltage (6 v) were tested in Adler tubes at a signal frequency of 550 Mc. The Brillouin gun gave a minimum noise figure of 1.31 (90° K) at a maximum gain of 30 db and a saturation gain of 50 db. The corresponding figures for the other gun, an immersed-flow type, were 1.4 (116° K), 22 db and 30 db.

621.385.6.032.269.1:621.391.822 1768
Study of the Noise Crossed-Field Guns—J. Arnaud and A. O. Doehler. (*J. Appl. Phys.*, vol. 33, p. 234; January, 1962.) The noise is shown to be due to an instability of the space charge in the entire gun region resulting in positive feedback on the cathode emission. Oscillation does not occur at a fixed frequency but is modulated by shot noise.

621.385.623:621.316.726 1769
Automatic Frequency Control for a Klystron J. M. Daniels and H. A. Farach. (*Rev. Sci. Instr.*, vol. 32, pp. 1262–1263; November, 1961) Circuit details are given of a practical negative-feedback stabilization system, simpler than the transistor circuit described by George and Teaney (746 of 1961).

621.385.623:621.317.361.029.6 1770
Phase-Stabilized Klystron System and its Application to Microwave Spectroscopy and Microwave Frequency Standards—Narath and Gwinn. (See 1655.)

621.385.623.5 1771
The Reflex Klystron as an Amplifier at 73 kMc/s—D. M. Makurat, R. C. Hertel, and K. Ishii. (Proc. IRE, vol. 50, pp. 210–211; February, 1962.) Report on experimental results. A maximum gain of 17.5 db was obtained, but no attempt was made to stabilize the amplifier or reduce the high noise figure.

621.385.624:621.397.61 1772
A High-Power Klystron for Television Transmitters in the Band IV Frequency Range—W. Schmidt. (*Nachrtech. Z.*, vol. 14, pp. 431–435; September, 1961.) Design details and operational characteristics of a four-cavity klystron with an output >10 kw.

621.385.63 1773
Some Characteristics of Certain Electrostatically Focused Devices—W. M. Nunn, Jr., and J. E. Rowe. (Proc. IRE, vol. 50, p. 89; January, 1962.) The conditions governing the application of an electrostatically focused fast-wave device for generation and amplification at microwave frequencies are considered.

621.385.63 1774
The Present Generation of Travelling-Wave Tubes—C. H. Dix. (*Electronic Eng.*, vol. 34, pp. 72–76; February, 1962.) A general summary of the construction, operation and performance or current types of traveling-wave tube.

621.385.63.032.269.1 1775
A Study of M-Type-Tube Electron Guns—T. Unotoro. (*Rev. Elec. Comm., Lab., Japan*, vol. 9, pp. 497–525; July/August, 1961.) Electron orbits in these guns have been investigated. New designs of plane and cylindrical guns, and convergent guns of the immersed type are described.

621.385.632 1776
The Transformation of Electron Waves in Low-Noise Beam-Generating Systems for Travelling-Wave Tubes—K. B. Niclas. (*Telefunken-Röhre*, no. 40, pp. 91–168; October, 1961.) Theoretical treatment of low-noise electron-gun design with particular consideration of the factors governing the minimum noise figure obtainable.

621.385.632:621.318.2 1777
The Magnetic Field Strength in Periodic Magnetic Focusing Systems—W. Henne. (*Telefunken-Röhre*, no. 40, pp. 73–90; October, 1961.) An analog method is given for calculating the field strength and field distribution in focusing systems for traveling-wave tubes. Values of air-gap field strength are plotted for various magnetic materials and as a function of magnet size. The effect of pole pieces is also investigated.

621.385.632:621.318.2 1778
The Design of Radically Magnetized Ring Magnets in Periodic Focusing Systems for Travelling-Wave Tubes—W. Henne. (*Arch. elekt. Übertragung*, vol. 15, pp. 429–436; September, 1961.) The advantages of radially over axially magnetized ring magnets are shown with reference to field-strength measurements.

621.385.632:621,318.2 1779
The Computation of the Magnetic Field Strength of Ring Magnets—W. Henne. (*Elektrotech. Z., Edn A*, vol. 82, pp. 819–823; December 4, 1961.) The use of a resistance-network analog is proposed for calculating the field strength of elements constituting the periodic focusing system of traveling-wave tubes.

621.385.633.24 1780
Energy Mismatch and Cut-Off Waves in a Two-Dimensional Space-Charge Flow—J. E. Rowe and R. Y. Lee. (*J. Appl. Phys.*, vol. 33, pp. 185–193; January, 1962.) A general treatment of the energy mismatch at the input boundary and subsequent excitation of cutoff waves in a planar space-charge flow. The method is applied to an M-type backward-wave oscillator; it can also be applied to other flow systems.

621.385.65:621.374.32 1781
Trochotron High-Speed Beam Switching Tubes—D. Reaney. (*J. Brit. IRE*, vol. 23, pp. 99–110; February, 1962.) A description of the tube and its circuit applications is given. Binary, single-pulse and sine-wave drive circuits are discussed and methods of extending the number of output channels and of generating staircase or analog waveforms are illustrated.

621.385.832 1782
The Barrier-Grid Storage Tube and its Use in Integration—R. J. Paul. (*Brit. Commun. Electronics*, vol. 9, pp. 28–32; January, 1962.) Techniques for achieving up to 2000 integrations per tube are described for integration periods ranging from tens of microseconds to tens of seconds.

621.385.833.032.269.1 1783
Grid-Controlled Fine-Focus Guns for Long Beam Throw—A. Sandor. (*J. Electronics and Control*, vol. 10, pp. 325–340; May, 1961.) Electrostatically and magnetically focused versions of a triode-type gun were developed for a 15-in. throw. A grid aperture of 0.015 in gave a spot size of 0.01 in with 100-μA beam current and 20–24-kv acceleration.

621.385.833.032.269.1 1784
Measurements of the Limiting Image Current Density produced by Electron Guns of Rotational Symmetry—H. Moss. (*J. Electronics and Control*, vol. 10, pp. 341–364; May, 1961.) Nonuniform cathode emission can cause errors in observations of the limiting density. Conclusions have been reached concerning the relations between a) the theoretical and measured density and b) the convergence of the beam and the current. The effects of different cathode materials have been studied.

621.387:621.362 1785
Thermionic Current Transmission in a Strong Magnetic Field.—Shock and Eisen. (See 1663.)

621.387:621.362 1786
Materials Problems in Cesium Thermionic Converters—Yang and Carpenter. (See 1662.)

MISCELLANEOUS

061.4:621.38 1787
Physical Society Exhibition—(*Wireless World*, vol. 68, pp. 117–126; March, 1962.) A description of some of the instruments and apparatus displayed at the 46th Annual Exhibition of the Institute of Physics and the Physical Society, London, January 15–19, 1962.

621.38.004.6 1788
Reliability Problems of Electronic Equipment—J. P. Rehahn. (*Nachtech.*, vol. 11, pp. 396–401; September, 1961.) Factors governing equipment reliability are reviewed. 112 references.

Translations of Russian Technical Literature

Listed below is information on Russian technical literature in electronics and allied fields which is available in the U. S. in the English language. Further inquiries should be directed to the sources listed. In addition, general information on translation programs in the U. S. may be obtained from the Office of Science Information Service, National Science Foundation, Washington 25, D. C., and from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

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ANE: Aeronautical and Navigational Electronics
AP: Antennas and Propagation
AU: Audio
AC: Automatic Control
BTR: Broadcast and Television Receivers
BC: Broadcasting (Formerly Broadcast Transmission Systems)
CT: Circuit Theory
CS: Communication Systems
CP: Component Parts
E: Education
ED: Electron Devices
EC: Electronic Computers
EM: Engineering Management
EWS: Engineering Writing and Speech
HFE: Human Factors in Electronics
IE: Industrial Electronics
IT: Information Theory
I: Instrumentation
ME: Medical Electronics
MTT: Microwave Theory and Techniques
MIL: Military Electronics
NS: Nuclear Science
PT: Production Techniques
RFI: Radio Frequency Interference
RQC: Reliability and Quality Control
SET: Space Electronics and Telemetry (Formerly Telemetry and Remote Control)
UE: Ultrasonics Engineering
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Zero Cancellation Synthesis Using Impedance Operators: CT Jun 114
Zeros of Transient Responses: CT Jun 109
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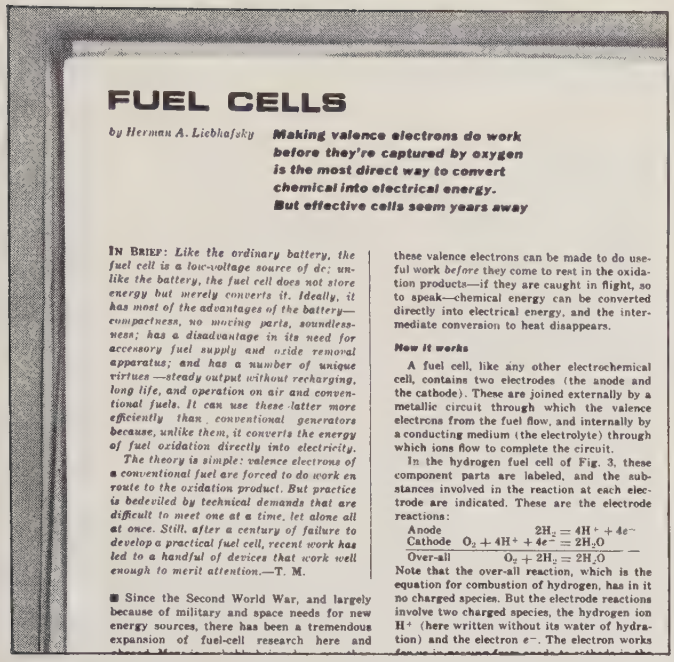


FUEL CELLS

by Herman A. Liebhafsky

Making valence electrons do work before they're captured by oxygen is the most direct way to convert chemical into electrical energy. But effective cells seem years away

IN BRIEF: *Like the ordinary battery, the fuel cell is a low-voltage source of dc; unlike the battery, the fuel cell does not store energy but merely converts it. Ideally, it has most of the advantages of the battery—compactness, no moving parts, soundlessness; has a disadvantage in its need for accessory fuel supply and oxide removal apparatus; and has a number of unique virtues—steady output without recharging, long life, and operation on air and conventional fuels. It can use these latter more efficiently than conventional generators because, unlike them, it converts the energy of fuel oxidation directly into electricity.*

The theory is simple: valence electrons of a conventional fuel are forced to do work en route to the oxidation product. But practice is bedeviled by technical demands that are difficult to meet one at a time, let alone all at once. Still, after a century of failure to develop a practical fuel cell, recent work has led to a handful of devices that work well enough to merit attention.—T. M.

■ Since the Second World War, and largely because of military and space needs for new energy sources, there has been a tremendous expansion of fuel-cell research here and

these valence electrons can be made to do useful work *before* they come to rest in the oxidation products—if they are caught in flight, so to speak—chemical energy can be converted directly into electrical energy, and the intermediate conversion to heat disappears.

How it works

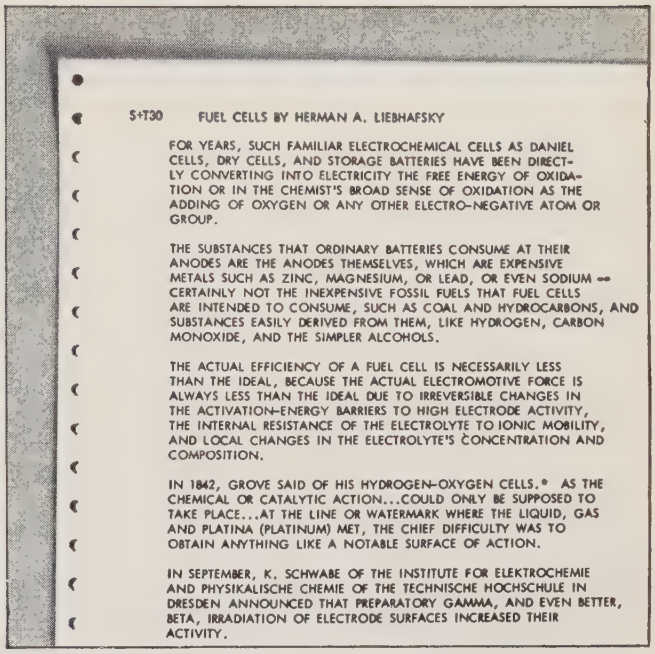
A fuel cell, like any other electrochemical cell, contains two electrodes (the anode and the cathode). These are joined externally by a metallic circuit through which the valence electrons from the fuel flow, and internally by a conducting medium (the electrolyte) through which ions flow to complete the circuit.

In the hydrogen fuel cell of Fig. 3, these component parts are labeled, and the substances involved in the reaction at each electrode are indicated. These are the electrode reactions:

Anode	$2H_2 = 4H^+ + 4e^-$
Cathode	$O_2 + 4H^+ + 4e^- = 2H_2O$
Over-all	$O_2 + 2H_2 = 2H_2O$

Note that the over-all reaction, which is the equation for combustion of hydrogen, has in it no charged species. But the electrode reactions involve two charged species, the hydrogen ion H^+ (here written without its water of hydration) and the electron e^-. The electron works

This 4000-word article appeared in the January, 1962, issue of International Science and Technology. *To abstract the article, a document analyst would read it, define its purpose, and summarize its essential points.*



S+T30 FUEL CELLS BY HERMAN A. LIEBHAFSKY

FOR YEARS, SUCH FAMILIAR ELECTROCHEMICAL CELLS AS DANIEL CELLS, DRY CELLS, AND STORAGE BATTERIES HAVE BEEN DIRECTLY CONVERTING INTO ELECTRICITY THE FREE ENERGY OF OXIDATION OR IN THE CHEMIST'S BROAD SENSE OF OXIDATION AS THE ADDING OF OXYGEN OR ANY OTHER ELECTRO-NEGATIVE ATOM OR GROUP.

THE SUBSTANCES THAT ORDINARY BATTERIES CONSUME AT THEIR ANODES ARE THE ANODES THEMSELVES, WHICH ARE EXPENSIVE METALS SUCH AS ZINC, MAGNESIUM, OR LEAD, OR EVEN SODIUM -- CERTAINLY NOT THE INEXPENSIVE FOSSIL FUELS THAT FUEL CELLS ARE INTENDED TO CONSUME, SUCH AS COAL AND HYDROCARBONS, AND SUBSTANCES EASILY DERIVED FROM THEM, LIKE HYDROGEN, CARBON MONOXIDE, AND THE SIMPLER ALCOHOLS.

THE ACTUAL EFFICIENCY OF A FUEL CELL IS NECESSARILY LESS THAN THE IDEAL, BECAUSE THE ACTUAL ELECTROMOTIVE FORCE IS ALWAYS LESS THAN THE IDEAL DUE TO IRREVERSIBLE CHANGES IN THE ACTIVATION-ENERGY BARRIERS TO HIGH ELECTRODE ACTIVITY, THE INTERNAL RESISTANCE OF THE ELECTROLYTE TO IONIC MOBILITY, AND LOCAL CHANGES IN THE ELECTROLYTE'S CONCENTRATION AND COMPOSITION.

IN 1842, GROVE SAID OF HIS HYDROGEN-OXYGEN CELLS.* AS THE CHEMICAL OR CATALYTIC ACTION...COULD ONLY BE SUPPOSED TO TAKE PLACE...AT THE LINE OR WATERMARK WHERE THE LIQUID, GAS AND PLATINA (PLATINUM) MET, THE CHIEF DIFFICULTY WAS TO OBTAIN ANYTHING LIKE A NOTABLE SURFACE OF ACTION.

IN SEPTEMBER, K. SCHWABE OF THE INSTITUTE FOR ELEKTROCHEMIE AND PHYSIKALISCHE CHEMIE OF THE TECHNISCHE HOCHSCHULE IN DRESDEN ANNOUNCED THAT PREPARATORY GAMMA, AND EVEN BETTER, BETA, IRRADIATION OF ELECTRODE SURFACES INCREASED THEIR ACTIVITY.

This abstract was prepared by an IBM computer. The text was first coded in machine language. The computer then counted key words, and printed out sentences having the greatest statistical significance

Each year in the physical and life sciences, some 50,000 technical journals will be published throughout the world. 100,000 research reports and 60,000 technical books will also be written. Somewhere in this mass of knowledge may be information you need. To tell what is known—and where to find it—IBM is investigating systems for the dissemination, storage, and retrieval of information.

To create an advanced information retrieval system, labels must be found for *all* useful information in documents. With conventional library indexing, it is difficult to make allowance for new kinds of knowledge. However, computers let us use more versatile methods of indexing. In one of these, the KWIC INDEX (Key Word In Context), a computer selects significant terms in the titles of documents, then prints them out as index entries.

Once indexed, characteristics of documents' contents can be used to notify people of their existence. The Selective Dissemination of Information system at IBM stores profiles describing individuals' interests. A new document's key words are matched against key words in a person's profile. If there is sufficient correlation, he is informed of the document. Profile matching can also be used to retrieve information by storing documents and feeding keyword queries through the system.

At present it is relatively difficult to get text into machine-readable form. However, the development of high-speed optical character readers, automatic language translators, and improved methods of capturing linguistic information at the source may make it possible to introduce information directly into retrieval systems. Once harvested, vast quantities of information will present storage problems. IBM is investigating random-access photostorage systems capable of storing millions of documents and retrieving them in seconds. Out of systems like these may come total information centers which will acquaint scientists and businessmen with all the information needed in their work.

If you have been searching for an opportunity to make important contributions in information retrieval, component engineering, optics, space systems, or any of the other fields in which IBM scientists and engineers are finding answers to basic questions, please contact us. IBM is an Equal Opportunity Employer. Write to: Manager of Professional Employment, IBM Corporation, Department 645 S, 590 Madison Avenue, New York 22, New York.

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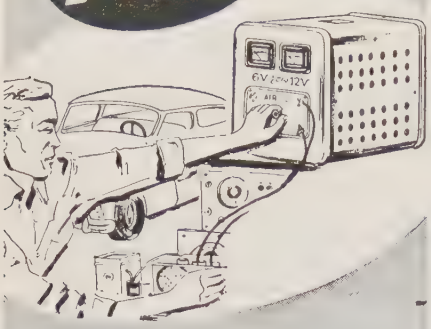

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IRE People

(Continued from page 83A)

William S. Grossman (A'60) former Independent Marketing Consultant, has been appointed Distributor Sales Manager of Arco Electronics, Inc., Great Neck, N. Y.

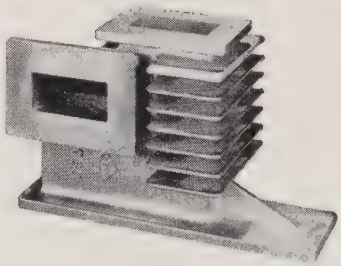
W. S. Grossman

Mr. Grossman, who comes to Arco with more than twelve years of experience in sales management, will supervise the marketing of Elmenco capacitors and Arcolytic electrolytic capacitors to industrial and service dealer distributors.

An army veteran of the European Theater, Mr. Grossman received a Bachelor's degree from the College of the City of New York in 1947. He has been a sales engineer with Fairchild Camera and Instrument Corp., Syosset, N. Y., and a sales manager of Beattie-Coleman Co., Anaheim, Calif.

❖

The appointment of **James R. Sink** (M'61) as Quick-Reaction-Products Manager of ACF Electronics has been announced.



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Mr. Sink, who joined ACF Electronics from the Department of Defense, is responsible for marketing the division's quick-reaction facilities in electronics engineering, modification, adaptation and production to both military and industrial organizations.

J. R. Sink

He was chief of the support branch, technical division, U.S. Army Signal Communications Security Agency, Arlington, Va., before joining ACF. Before joining the Department of Defense as a civilian in 1947 he served in the U. S. Army Signal Corps in the European Theater where he was awarded the Bronze Star for action in World War II.

❖

The appointment of **Joseph DeVincent** (A'50–M'60) as Plant Manager for ACF Electronics, Paramus, N. J., has been announced.

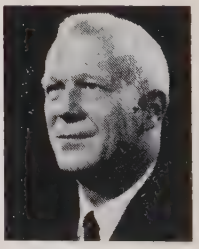
Prior to this appointment Mr. DeVincent served as the plant's Manager of Engineering and Research. He joined ACF in 1948 and advanced through a number of positions to direct the microwave equipment laboratory and later all engineering and technical activities in the plant's four major laboratories.

J. DeVincent

He is a member of the AIEE and is Secretary of the North Jersey Subsection of the American Astronautical Society. He holds Bachelor's and Master's degrees in electrical engineering, both earned at the College of the City of New York, in 1948 and 1953 respectively.

❖

Ivan G. Easton (S'39–A'41–SM'45–F'60), Vice President of Engineering, General Radio Company, West Concord, Mass., has been appointed to panel 14 of the National Academy of Sciences, which serves as an advisory body to the Instrumentation Division of the Bureau of Standards.

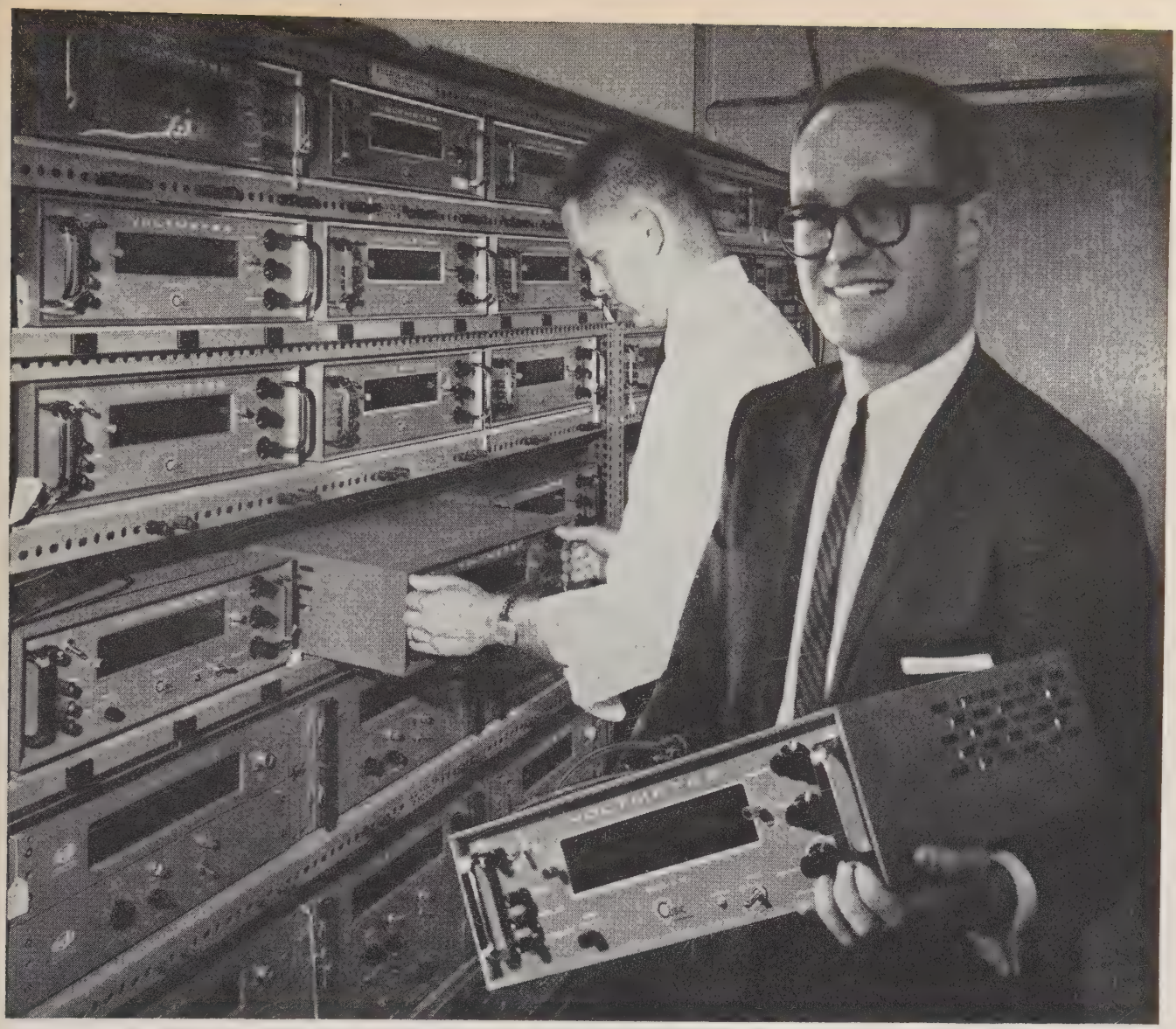


I. G. Easton

This group, meeting annually in Washington, discusses developments in the field, makes critical evaluations of the work in progress and presents recommendations for the future.

❖

(Continued on page 140A)



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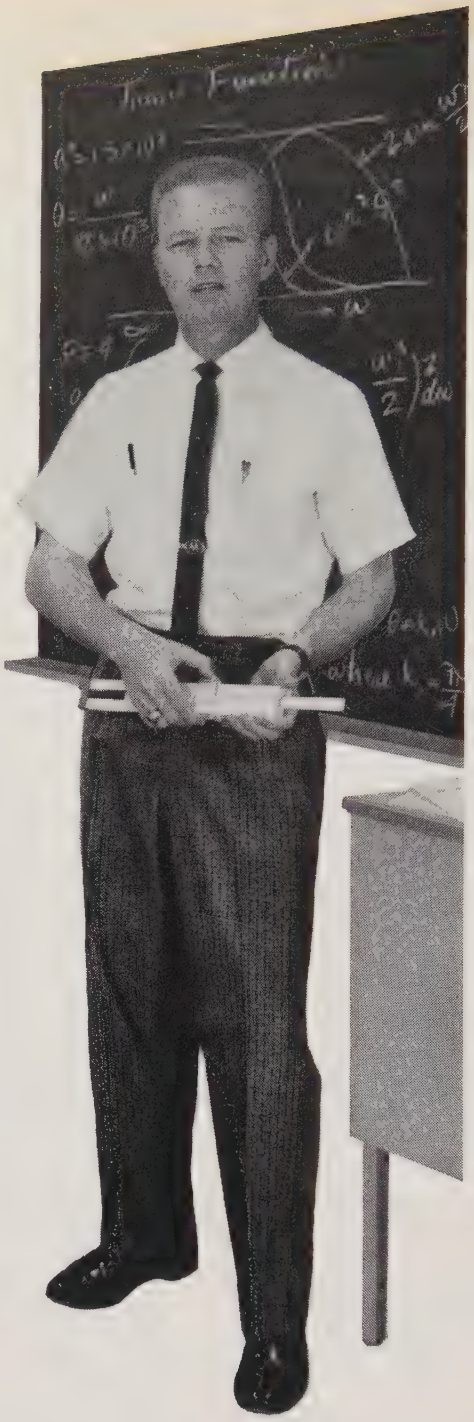

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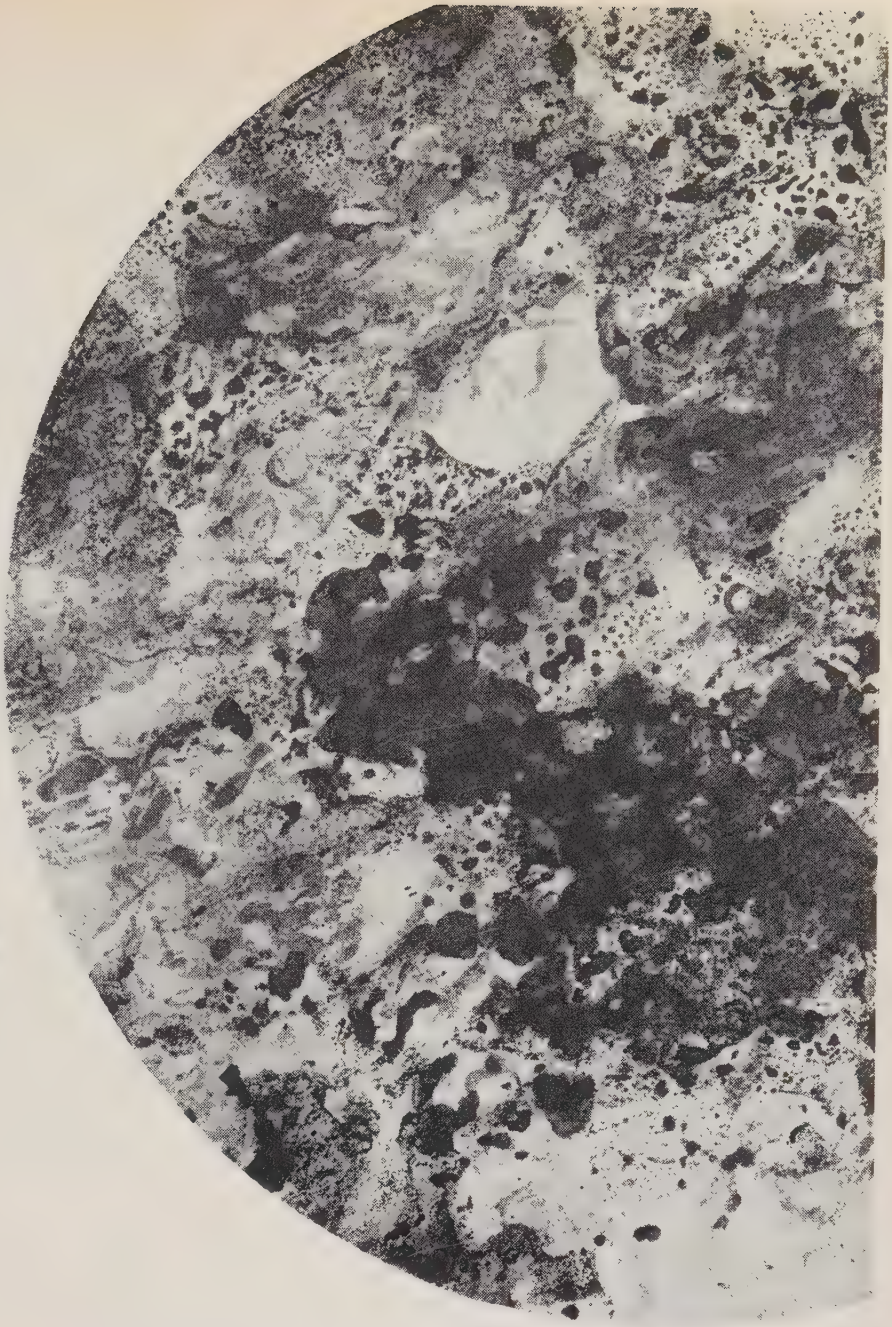
(Continued on page 90A)



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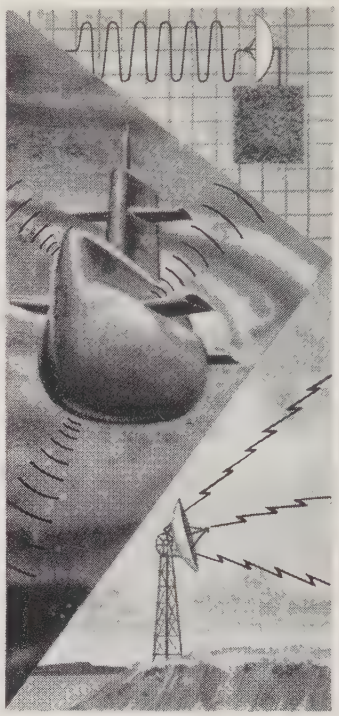

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Positions Open

(Continued from page 88A)

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(Continued on page 94A)

AND GROW

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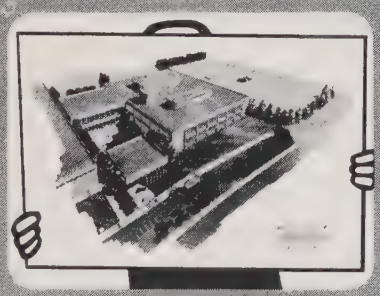

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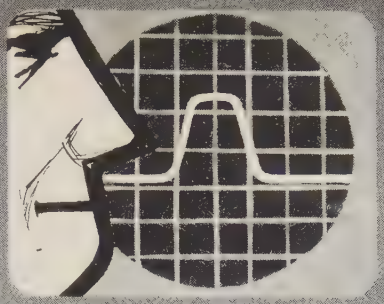

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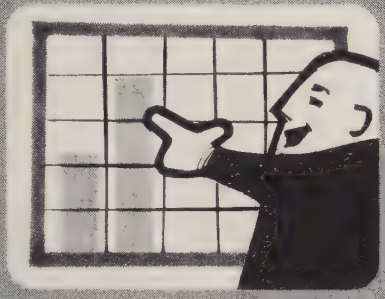

If you're looking for growth, Lenkurt Electric is one of the largest employers in the area and has increased its staff by 45% in the last 18 months.

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Also, Lenkurt has had an average growth rate of 18% per year over the last 10 years—the result of increased business in solid, dependable commercial markets, not one-time contracts.

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A new $2-million Research and Development Center reflects the Lenkurt Electric growth plans for the future.

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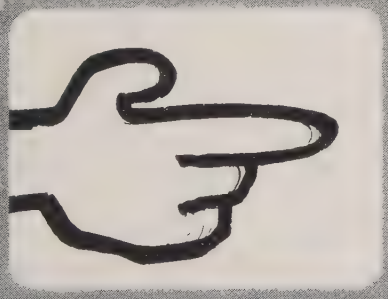

Ask for it.

Write or phone E. Jack Shannahan, Engineering Placement Manager, Lenkurt Electric Co., Inc., San Carlos, California. DDD 415, LYtell 1-8461, Ext. 281

Fill this form with the proper information and send it in.

E. Jack Shannahan, Engineering Placement Manager
Lenkurt Electric
1105 County Rd.
San Carlos, California

Please send the illustrated information packet on Lenkurt engineering opportunities, product line, Bay Area schools, living conditions, and recreation.

Your Name: _____

Address: _____

City _____ State _____

Telephone No. _____

Degree Level: B.S. _____ M.S. _____ Ph.D. _____

Current Title _____

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Positions Open

(Continued from page 90A)

Ph.D. or equivalent required. Reply to Dr. T. S. Peterson, Chairman, Division of Science. Portland State College, Portland 1, Oregon.

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Minimum 2 yrs. experience design of audio, power, MIL and industrial transformers. Expanding to multi-plant operations, both coasts. Top salary, full benefits, profit and pension plans. West Coast telephone 213-HO 3-5694; East Coast telephone 516-LOcust 1-6050. Person to contact for interview arrangements, Mr. Richard K. Chaber, Vice President, Engineering, at 516-LOcust 1-6050, Microtran Company, Inc., Valley Stream, N.Y.

ELECTRONICS ENGINEER, B.S. or M.S.

Unique opportunity in small expanding company for a versatile and resourceful man trained in RF techniques, field theory, general electronics, feedback amplifier design and servomechanisms. Development, prototype and initial production runs. Minimum 3 years experience desirable. Reply to Boonton Polytechnic Company, P.O. Box 125, Boonton, New Jersey.

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Staff positions beginning September, 1962. Undergraduate-graduate teaching and research in networks, systems, microwaves, and materials. Write to Joseph C. Michalowicz, Head, Department of Electrical Engineering, The Catholic University of America, Washington 17, D.C.

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Ph.D. with teaching experience to be Department Head. To handle advanced undergraduate courses and to initiate research. College of liberal arts and sciences. Resume to: R. B. Winslow, Department of Physics, Wheeling College, Wheeling, W.Va.

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B.S. in EE with experience in electron tube and transistor circuits for work on design, development and application of phase measuring instruments. Any nationality. Permanent position. Pleasant working conditions. Salary commensurate with ability and experience. Detailed resume to Ad-Yu Electronics Lab., Inc., 249 Terhune Avenue, Passaic, New Jersey.

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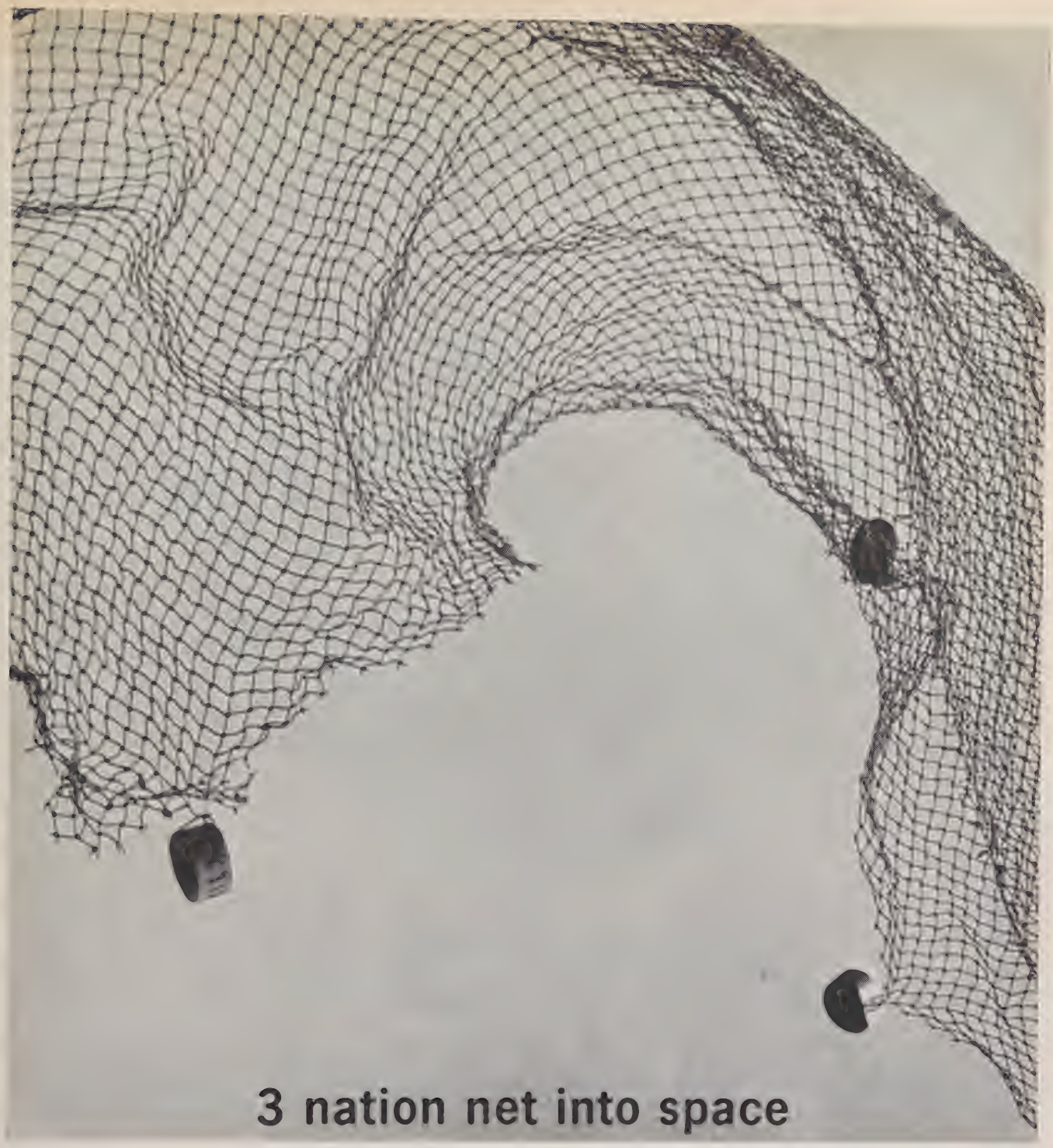
B.S. in Physics, EE or ME. Two or more years experience selling specialized mechanical or electro-mechanical equipment (expensive, semi-custom made items). Must be able to understand customers' special technical requirements and work out engineering solutions, such as modification of standard equipment to meet requirements. Travel half the time and will work with minimum guidance and support. Must be capable of working with clients on all details including financial. Address your resume to: Mr. Donald Sweet, Arthur D. Little, Inc., 35 Acorn Park, Cambridge 45, Mass. An equal opportunity employer.

MANUFACTURING ENGINEER

Redesign of breadboard models of highly engineered electromechanical equipment for cost reduction and semi-mass production. Experienced in mass and semi-mass production operations. Would build manufacturing competence over an

(Continued on page 98A)



3 nation net into space

Goldstone, Calif. Woomera, Australia. Johannesburg, South Africa.

Three tiny spots on the map that make up the most advanced space communications network on Earth: the Deep Space Instrumentation Facility.

Directed by Caltech's Jet Propulsion Laboratory, DSIF does two jobs. It sends and receives signals millions of miles to and from space. And it tracks spacecraft that will fly-by, orbit and land on the moon and planets.

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The space age is the age of specialization. JPL needs experts — inquisitive specialists who want to know what the moon is made of, if there's life on other planets and how the solar system was formed. Men who want to pit their knowledge against the unknown. If you're that kind of expert, JPL is your kind of place.

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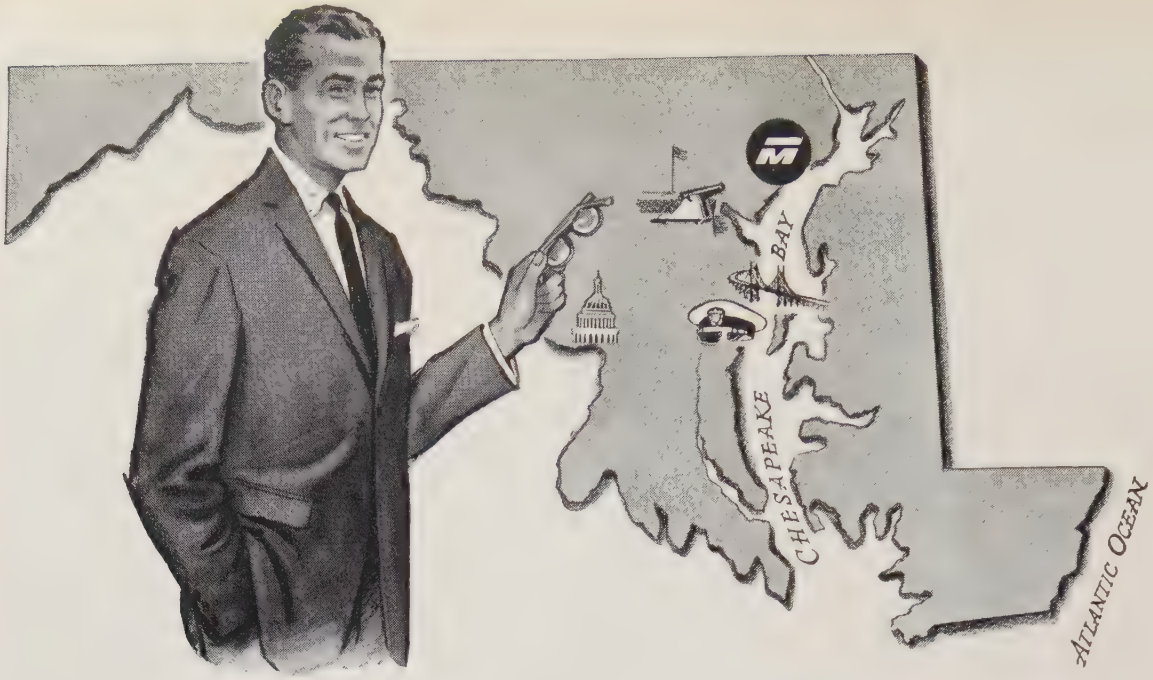
All qualified applicants will receive consideration for employment without regard to race, creed or national origin / U.S. citizenship or current security clearance required.



MARTIN moves ahead in MARYLAND

At the Martin Company, Aerospace Division of Martin Marietta Corporation, we have openings for qualified GRADUATE ENGINEERS and SCIENTISTS in our:

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With our extensive and successful experience in this field, we are rapidly moving ahead on challenging, advanced electronic programs at our Baltimore location.

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If you are qualified, by virtue of education, experience and interest, please write Mr. J. W. Perry, Manager of Professional Employment, Martin Company, Dept. E-30, Baltimore 3, Maryland.

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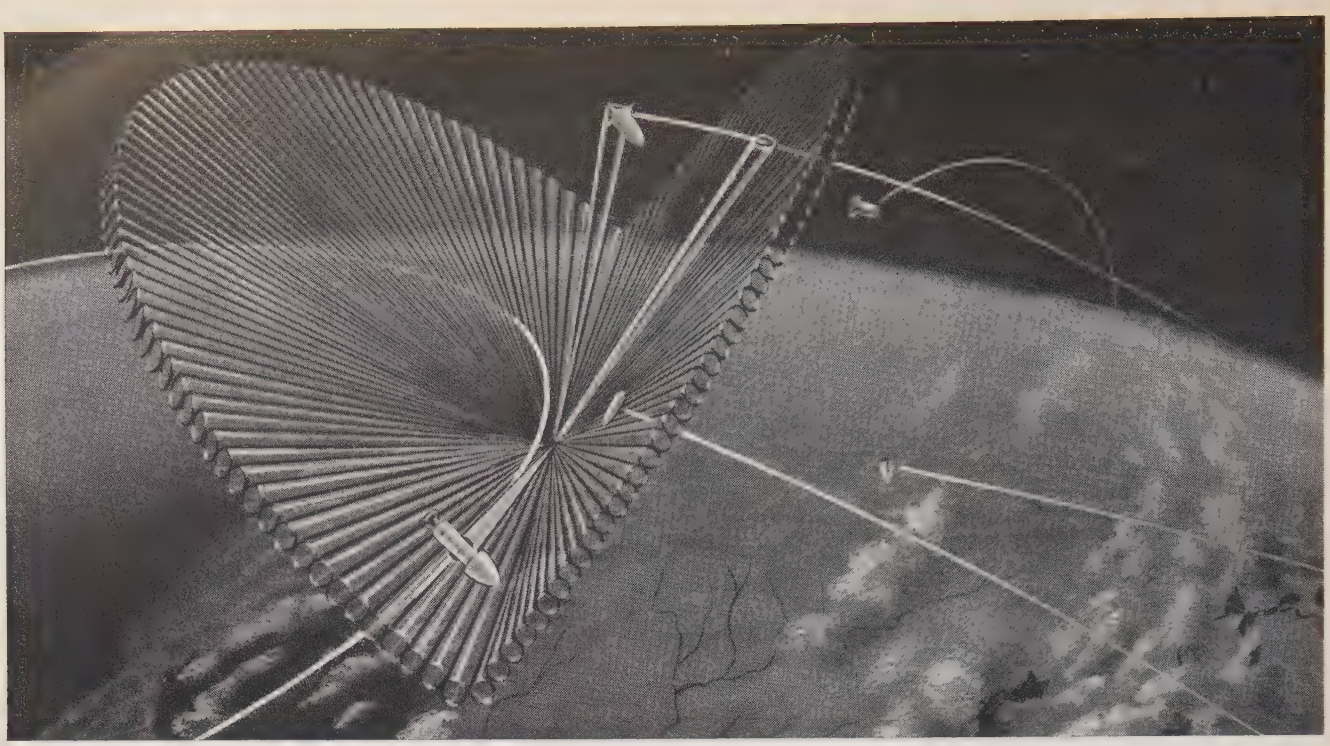

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Major projects at Hughes-Fullerton in Southern California include multidimensional, electronically-scanned, array radars for defense and space systems and a variety of even more advanced R & D contracts and studies.

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- **Pulsed Doppler**
- **Pulse Compression**
- **Automatic Detection**
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HUGHES

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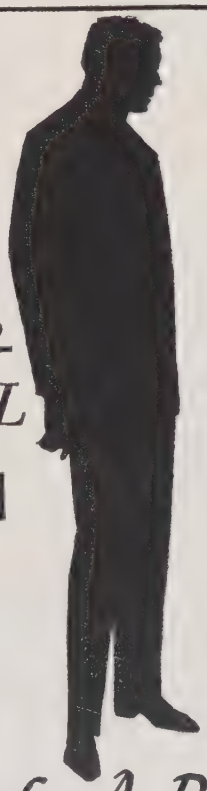

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Positions Open

(Continued from page 94A)

R&D base with a thorough knowledge of the problems involved, i.e., when to modify a design to overcome a problem. Address your resume to: Mr. Donald Sweet, Arthur D. Little, Inc., 35 Acorn Park, Cambridge 45, Mass. An equal opportunity employer.

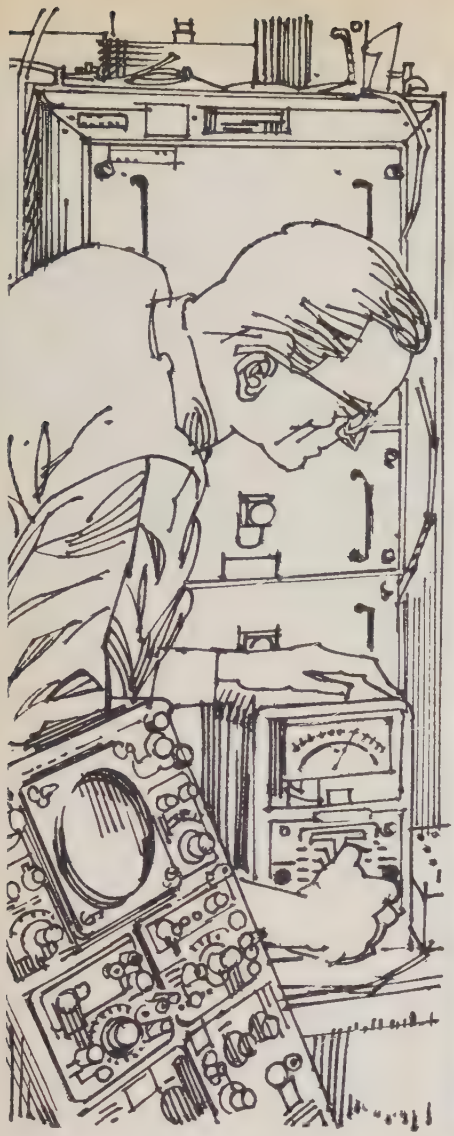
SCIENCE SPECIALISTS

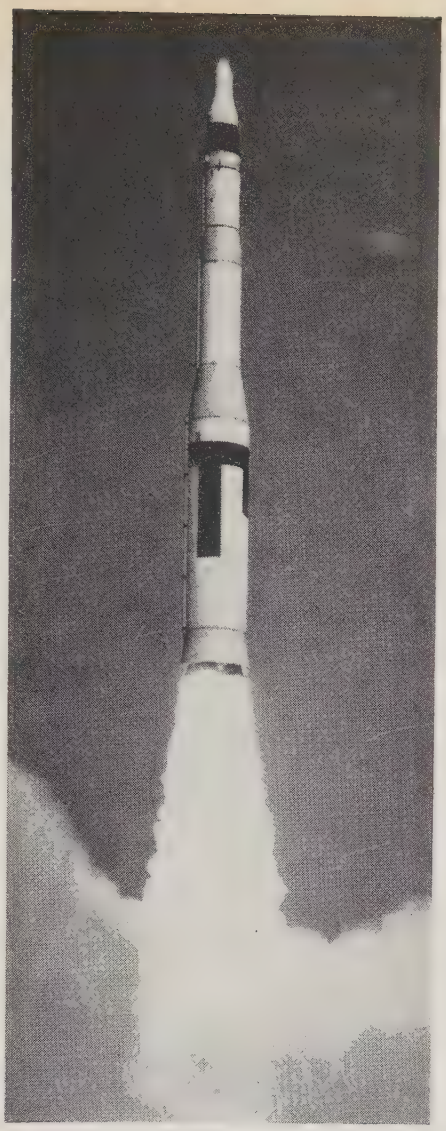
Positions are available for Research Specialists, grade GS-11, $7560, grade GS-12, $8955, and Senior Research Specialists, grade GS-13, $10,635 per year, in the following fields: Physics, geophysics, aerodynamics, thermodynamics, and aircraft design. Knowledge of Russian is desired. Grade commensurate with qualifications. Moving expenses will be paid and on site personal interviews will be arranged. Interested persons please send Standard Form 57 (Application for Federal Employment) to the Personnel Office, Library of Congress, Washington 25, D.C.

SENIOR ELECTRONIC SCIENTIST

Electronics Engineer, or Physicist with circuits background, for work in a Research Laboratory. Position will involve application of thermionic, solid state and microwave techniques to measurements and control problems. The person filling this position will work with minimum supervision and carry projects from conception through laboratory or field application. Recent M.S. degree preferred. Send resume and salary requirements in confidence to Personnel Relations Department, Continental Oil Company, Ponca City, Oklahoma.

(Continued on page 102A)



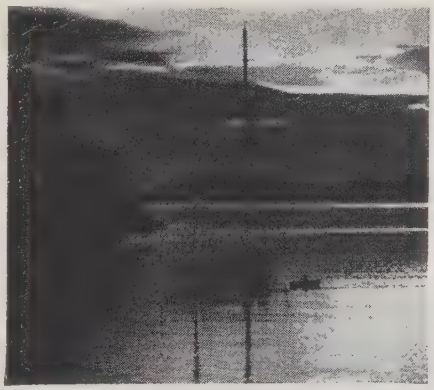


BOEING OPENINGS FOR ELECTRONIC/ELECTRICAL ENGINEERS

Boeing's Aero-Space Division, holder of major contracts on such advanced space programs as SATURN, DYNA-SOAR and MINUTEMAN, has a number of immediate, long-range openings offering professional challenge, and in many instances, unique ground-floor opportunities in newly-formed divisional organizations.

ELECTRONIC/ELECTRICAL engineering assignments are available in many areas, including the design of electronic equipment, the development of improved design techniques, electronic parts, electronic packaging techniques and the design and development of improved electronic systems.

Salaries are commensurate with all levels of education and experience. Minimum requirements are a B.S. degree in any applicable scientific discipline. Most of the assignments are in the uncongested Pacific Northwest, offering outstanding family living and recreational advantages.



Send your resume, today, to Mr. Wm. B. Evans, The Boeing Company, P.O. Box 3707-PRQ, Seattle 24, Washington. The Boeing Company is an equal opportunity employer.

P.S. Seattle is the scene, April 21 to October 21, of the science-oriented Century 21 World's Fair. The Fair's Boeing-sponsored Spacearium in the Science Pavilion offers simulated flights through outer space. Fair visitors are invited to stop in at the Boeing Professional Employment Information Center, near the Fair's Science Pavilion entrance.

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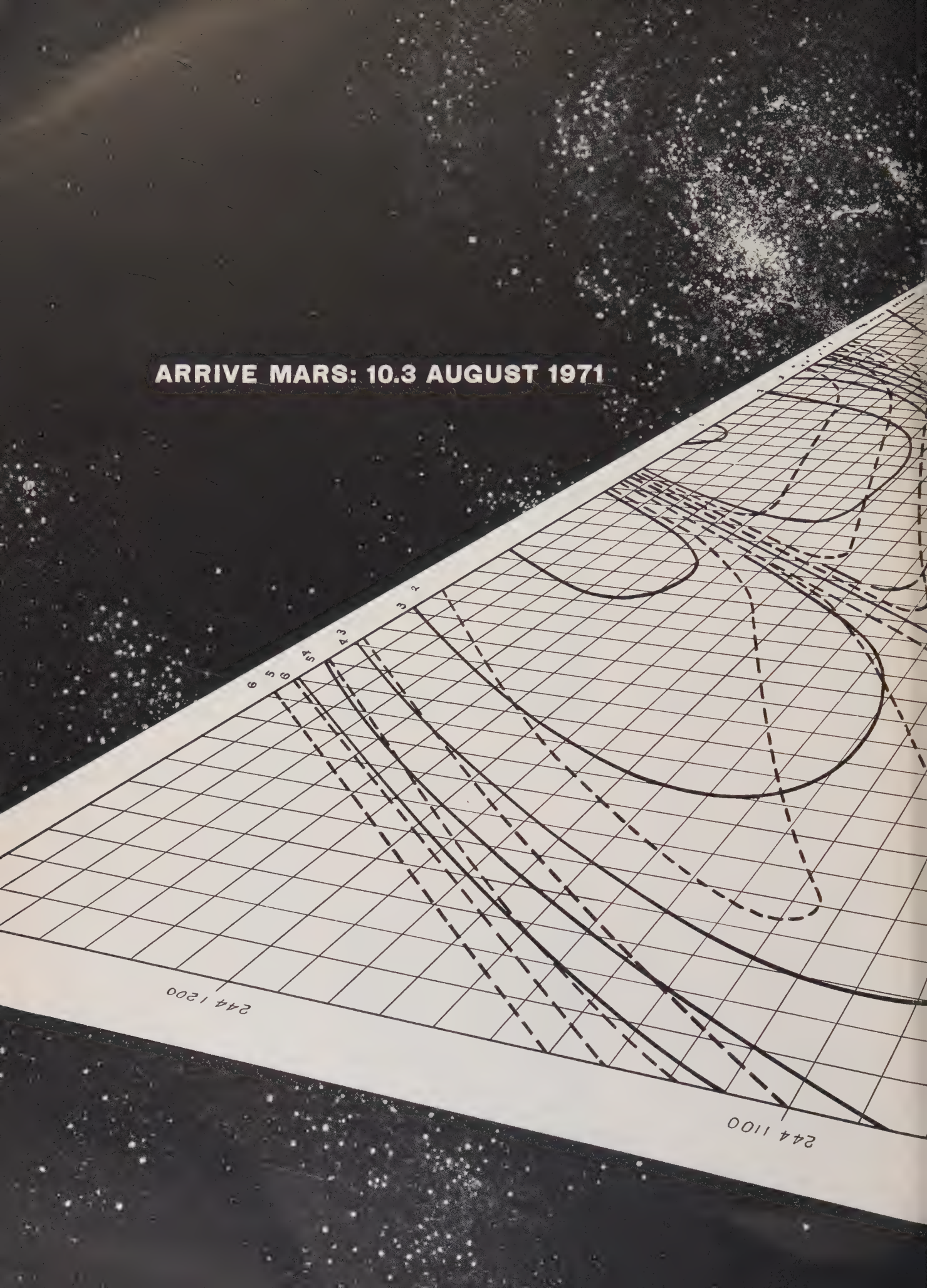
ARRIVE MARS: 10.3 AUGUST 1971
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244 1100

Giant steps were taken recently at Lockheed Missiles & Space Company toward manned exploration of the planets Mars and Venus. For the first time, accurate interplanetary transfer orbits have been plotted to show velocities as related to departure and arrival dates for an entire cycle of planet oppositions. A "fast" round-trip would take a year, allowing perhaps ten days exploration time on Mars.

A preliminary but comprehensive study also was made on the spacecraft's design considerations. Many facets were explored—configuration, single versus multi-stages, weight, thrust, payload, exploring, landing, and return equipment; and many more. The arresting conclusion of Lockheed scientists: *A vehicle can perform such a mission within the present state-of-the-art.*

Engineers and scientists at Lockheed Missiles & Space Company conduct many other feasibility and research studies, probing for advanced knowledge in a wide diversity of disciplines. Lockheed's constant expansion, its growing leadership in missiles and space, its ever-widening scope of projects, its ideal location on the beautiful San Francisco Peninsula—all open new and unusual challenges to well-qualified people.

For further information, please write: Research and Development Staff, Department M-25G, 599 North Mathilda Avenue, Sunnyvale, California. Lockheed is an equal opportunity employer.

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Systems Manager for the Navy POLARIS FBM and the AGENA vehicle in various Air Force Satellite programs. Other current projects include such NASA programs as OGO, ECHO and NIMBUS.

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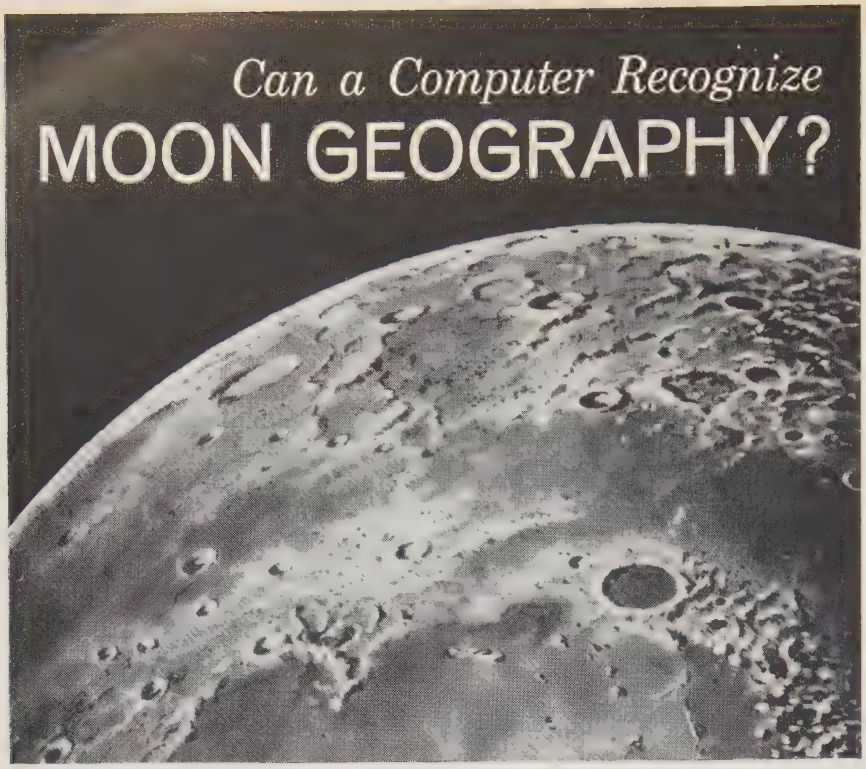

• Cornell Aeronautical Laboratory's engineers and scientists are investigating concepts for computers which can be "taught" to recognize patterns, whether those patterns be airfields, missile sites — or even significant topographic features of the moon. In related areas, CAL is developing special purpose computers surprisingly small in size, yet faster for the task than the speediest general purpose computers in use today. These computers use novel delay line storage techniques to perform computations in real time.

As a research tool in our cognitive systems program, a special input facility for the IBM 704 digital computer has been developed, allowing photographic data to be inserted directly into the computer. This facility allows CAL engineers to implement and evaluate pattern recognition concepts at an early stage in the research program.

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Positions Open

(Continued from page 98A)

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Electronic Engineer (3)	GS-5	$5335 pa
Industrial Engineer	GS-7	$6345 pa
Research Psychologist (Physiological, Experimental & Engineering)	GS-7	$5355 pa
Research Psychologist (Engineering)	GS-9	$6435 pa
Mechanical Engineer	GS-11	$7560 pa
Electronic Engineer (2) (Electro Magnetics)	GS-11	$7560 pa
Electronic Engineer (Gen.)	GS-11	$7560 pa

Positions Wanted

By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

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Professional Electronics Engineer with 12 years experience in a wide range of Communications and Medical-Industrial Electronics equipment and systems design and good sales background, seeks appointment as Manufacturers Representative for a good line of electronics equipment or instruments. Box 3983 W.

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Would enjoy coordinating the research efforts of a laboratory with related research done in other countries—to avoid duplication and accelerate results. Training includes: mathematics, management, manufacturing, engineering, graphic arts, Russian, German, French, etc. Interested in automatic language translation. (home: Philadelphia; age: 41) Box 3982 W.

ELECTRONIC ENGINEER

MSEE, 3 years experience in transistorized digital systems for space probe payloads. Desires to do creative work in same or a similar field. Prefers smaller company or autonomous division of larger company. Available in late summer. Write Box 3991 W.

ACADEMIC POSITION

B.S. and M. S. in E.E.; 3 years teaching in a university EE department prior to entering USAF for three years. Have begun work on

(Continued on page 104A)

The great paradox of our time, perhaps of all time, is that peace depends on our capacity to fight a war. Thus the person who contributes to our military strength, contributes to the cause of world peace.

MITRE's contribution is the design of command and control systems to give our military commanders the means to detect attack and retaliate.

The men who design these systems must think in terms of war and military operations — weapons, logistics, communications, intelligence, ability to destroy and ability to survive. They must be able to predict and solve the problems of future military command within the reality of existing or predictable electronic capability.

We call this "Military Command Technology."

MITRE's specific assignment is the design, development, evaluation, and integration of several interrelated, constantly evolving systems. It encompasses Command Systems such as NORAD; Control Systems (such as SAGE); Intelligence Systems (such as MIDAS); and Warning Systems (such as BMEWS).

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WAR

How would it be fought?

What would this nation's strategy be?

What kind of decisions would have to be made?

How would the commander command?

Who and what would survive?

MITRE is an independent, nonprofit corporation working with — not in competition with — industry. Formed under the sponsorship of the Massachusetts Institute of Technology, MITRE serves as Technical Advisor to the Air Force Electronic Systems Division, and is chartered to work for such other Government agencies as FAA.

In Camden, N.J., a dedicated group of RCA engineers is making important contributions to the development of advanced aerospace communications systems for projects like Dynasoar and Data Link. These are men of long experience, highly trained in their specialties, professional in every respect.

They are part of RCA's Aerospace Communications and Controls Division, where engineers (EE's or ME's) and managers now are needed. If your technical skill and creative processes are at the highest level, you may be assigned to problems as diverse as these:

DIGITAL: Logic Design; Digital Circuit Design—transistorized and magnetic; Systems Design and Analysis.

RF: Solid State Circuits—VLF to K band; Varactor Multipliers; Solid State Power Amplifiers; Ultralinear Mixers.

PROJECT ENGINEERING AND SYSTEMS INFORMATION: Subsystems for Aerospace Craft; Definition of Interface Requirements; Development of Specifications; Engineering Administration.

ADVANCED TECHNIQUE APPLICATIONS: Molecular Electronics Technology Applied to RF and Digital Communications.

To arrange an interview with engineering management, send your résumé to:

Mr. G. W. Faiss, Dept. PR-62
Radio Corporation of America
Bldg. 10-1
Camden 2, N.J.

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RADIO CORPORATION OF AMERICA

Positions Wanted

By Armed Forces Veterans

(Continued from page 102A)

Doctorate. Desire teaching position in Fall of 1962 with opportunity for graduate study. Write Box 3992 W.

ELECTRICAL ENGINEER

USAF Officer. 44 BSEE 1940, MSEE 1957, Reg P.E. 1947. Experience: radar, communications, electronic intelligence and R&D in Special Weapons Fuzing. Prefer Southwest or possibly overseas. Available August 1962. Write Box 3993 W.

FREQUENCY AND INTERFERENCE SPECIALIST

Retiring officer, 25 years radio & communication experience civil & USAF, desires full or part time position in warm climate. Extensive experience international frequency allocation, and management of operation and maintenance functions. Available Fall of 1962. Write Box 4000 W.

TECHNICAL PUBLICATIONS ENGINEER

Presently Director of Technical Publications and Advertising. Seeks challenging position with increased scope and responsibility. Experience includes ten years of radar and microwave technology and three years in advertising and public relations. Write Box 4001 W.

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B.S.E.E.—1951. Proficient in micro volt level amplifier design, feedback system analysis, active filter design, and digital circuit design. Desires to work on problems concerned with the life process or on the development of devices for supplementing man's sensory perception. Location on West Coast desirable. Write Box 4002 W.

ELECTRONIC ENGINEER

B.S. (Appl. Phys.), married, age 36. Knowledge of German, Polish, Russian. U.S. Citizen with 12 years of experience in instrumentation research and development. Desires position as Field Engineer for systems installation and customer liaison. Would consider Central European assignment. Write Box 4003 W.

ENGINEER IN FRANCE

American, 36, MSEE, 8 years experience radar systems and 4 years experience professional audio, seeks position or representation full or part time in Paris, France. Fluent French. Write Box 4004 W.

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B.S. Physics, 1958, 4½ years industrial research in Solid State Physics. Veteran USMC, 2 years aviation electronics technician. Married, family, 29 years of age. Seek foreign employment with managerial responsibility. Write Box 4005 W.

COMMUNICATION ENGINEER

B.S. '52. Age 31, married. 10 years in management and engineering of complex communication systems (radio, radar, teletype, telephone inside and outside plant). Valid FCC radiotelephone/telegraph licenses with radar and aircraft endorsements. Seeking position in sales or applied engineering western U.S., preferably Pacific coast. Write Box 4006 W.

(Continued on page 106A)

ACHPHENOMENON

Somewhere between the problem of forming six matches into four equilateral triangles and seeing the solution as a tetrahedron ..... Achphenomenon occurs. Call it insight, inspiration, or perception. It is that sudden impulse to think in another direction. Such impulses have produced our greatest achievements.

We welcome engineers who think in new dimensions, who form uncommon conclusions, who are not afraid to go outside the confines of accepted concepts. Insightful thinkers are invited to send a resume to Mr. Don D. Krause, Manager Professional and Scientific Staffing. You may expect prompt attention.

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To evaluate advanced system techniques and to apply new techniques to systems problems, with emphasis on navigation, traffic control, communications, and electromagnetic warfare. BS or MS in EE.

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Duties involve design, development, and testing of electronic instruments and equipment used in R & D programs in high atmosphere physics, meteorology and oceanography. BS, MS, electronics and experience in physical measurements, electronic circuitry, electromechanical devices and transducers

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Positions Wanted

By Armed Forces Veterans

(Continued from page 104A)

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Section Meetings

AKRON

"Ion Engines For Space Travel," W. R. Mickelson, NASA Lewis Research Center; 10/17/61.

"Error Control in Real Time Digital Computer Appl." G. M. Griffith, Remington Rand Corp.; Joint with PGEC: 11/21/61.

"Communication and Navigation in Space," Mr. P. Iribe, Westinghouse Air Arm: Joint AIEE & Professional Engineers; 12/12/61.

"Art of Navigation or Just How Do We Really Navigate?" R. Abraham, General Precision; 1/16/62.

ALAMOGORDO-HOLLOMAN

"The Two Megawatt Transmitter at Cutler Maine," M. W. Bullock, Continental Electronics; 2/20/62.

Annual Election of Officers; 3/20/62.

ALBUQUERQUE-LOS ALAMOS

"LOFTI Experiments," L. S. Bearce, U. S. Naval Research Lab.; 3/21/62.

ATLANTA

"Electronic Editing of Video Tape," F. D. Benson, Ampex Corp.; 3/23/62.

BALTIMORE

"Piezoelectricity and its Modern Applications," C. P. Germano, Clevite Corp.; Joint with AIEE; 3/12/62.

"BMEWS; Its Present and Future in Missile and Satellite Surveillance," S. G. Miller, RCA Corp.; 4/9/62.

BEAUMONT-PORT ARTHUR

"Magnetic Tape Recording," A. L. Musick, Sun Oil Co.; 3/13/62.

"Computers Past and Present," J. P. Buchanan, IBM Corp.; 4/10/62.

BINGHAMTON

"On-Line Data Transmission," G. J. Saxenmeyer, IBM Corp.; 3/12/62.

BUFFALO-NIAGARA

"Computer Uses I," S. Asseo & B. McDonald, Westinghouse Co.; 3/21/62.

CANAVERAL

"MISTRAM System," A. Sanders, General Electric; 3/15/62.

CEDAR RAPIDS

"Generation of Submillimeter Waves," P. D. Coleman, Univ. of Illinois; 3/14/62.

(Continued on page 108A)

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Since problems of extreme complexity cannot always be solved by a research team trained in a single scientific discipline, interdisciplinary communication is encouraged at Armour. Each team has access to the capabilities and facilities of the entire Foundation which conducts research, development and experimental engineering studies in seven varied areas: electronics, physics, metals and ceramics, chemistry, fluid dynamics and systems, and mechanics.

And, the staff keeps channels of communication open between the practitioners of fundamental science and the engineers who provide practical application of new ideas; basic research groups work alongside engineering and development groups.

The Electronics Division at Armour is initiating new analytical and hardware studies in such varied areas as bionics, systems analysis, millimeter waves, power conversion, automata, artificial simulation, VLF, solid state microwave components, computer elements, advanced magnetic recording techniques, microelectronics and medical electronics.

Extensive equipment and facilities are available to the Electronics Engineer at Armour, including an IBM 7090 and a Univac 1105. Because of a simplified programming language, the 1105 can be used by all members of the ARF staff after minimum training.

RESEARCH & DEVELOPMENT POSITIONS IN CHICAGO

EE's or Physicists with some experience preferred in one of the following areas: radar, antennas, circuit development, microwaves, radio interference, analysis, guidance and control, propagation, communications, signal processing, semiconductor devices, measurement techniques, computer systems, reliability analysis, component development.

Candidates for these positions should send resume to Mr. Ron C. Seipp, Armour Research Foundation, 10 West 35th Street, Chicago 16, Illinois.

ELECTROMAGNETIC COMPATIBILITY — ANNAPOLIS, MARYLAND

In recent years, the vastly increased power, sensitivity and amount of new electronic equipment have created a radio frequency interference crisis now being met by an extensive compatibility program. Armour Research Foundation has been given the responsibility for the technical supervision of the DOD's Electromagnetic Compatibility Analysis Center in Annapolis.

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SYSTEMS PROGRAMMERS, OPERATIONS ANALYSTS AND ENGINEERING MATHEMATICIANS/ STATISTICIANS to work in the design of generalized input-output packages, debugging routines, large data files and retrieval systems, developing models of military systems for computer simulation. These positions require a BS degree with experience in programming for large-scale digital computers, operations research, statistical analysis or application of digital computers to systems analysis.

There are openings also for

SYSTEMS ANALYSIS ENGINEERS requiring BS degree, with some experience desirable in radar and communications systems analysis, electronic system measurement techniques, spectrum signature measurement, signal environment analysis or microwaves, antennas and propagation.

Applicants for these positions should address resumes to Mr. S. M. Ream, Armour Research Foundation, USNEES, Annapolis, Maryland.

RADAR SYSTEM DEVELOPMENT— SILVER SPRING, MARYLAND

Another of the Armour Research Foundation's current projects requires the formation of a research team in Silver Spring for the development and evaluation of an advanced radar system having search, track and track-while-scan modes of operation. Assignments here will provide an opportunity to work on an entire weapon system, as well as to grow professionally in areas of development and analysis.

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All positions with Armour provide an opportunity to join one of the leading independent not-for-profit research organizations in the country, which undertakes between 600 and 800 projects annually, for approximately 300 companies and 35 government agencies. Attractive salaries, tuition-free graduate study and unusually liberal vacations are among the additional advantages. Inquire about YOUR career with Armour now!

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Section Meetings

(Continued from page 106A)

CENTRAL PENNSYLVANIA

"Can a Computer Think?" D. T. Laird, Pennsylvania State Univ.; Joint with AIEE; 1/23/62.

"Data Communications," R. K. McCutcheon, Bell Telephone Co.; Joint with AIEE; 2/20/62.

"An Introduction to Monopulse Antennas," W. H. Nester, General Electric; Joint with AIEE and Central Pa. Chapter of PGAP; 3/20/62.

CHICAGO

"Perceptrons and the Theory of Neurodynamics," F. Rosenblatt, Cornell Univ.; 4/13/62.

CHILE

"Tracking of Artificial Satellites," F. C. Isely, NASA; 9/1/61.

CHINA LAKE

"Should IRE and AIEE Consolidate?" Discussion by Section members and guest members from LA Section; 3/28/62.

COLOMBIA

"Programming In Computers," J. A. Lopez; IBM Corp.; 2/16/62.

COLUMBUS

"Optical Recognition Computer Language Translation," J. B. Cornelison, IBM Corp.; 3/13/62.

DALLAS

"Decision Making in Pattern Recognition," G. Sebestyen, Litton Industries, Communications Sciences Lab.; 2/15/62.

"Introduction to Matched Filters and Applications," A. R. Teasdale, Aerospace Division, Martin Marietta Corp.; 3/1/62.

"Two Years of Vela Uniform—A Progress Report," C. C. Bares, Nuclear Test Detection Office; 3/6/62.

"Theory of Coding and Applications," G. Solomon, Cal Tech Jet Propulsion Lab.; 3/8/62.

DENVER

"Network Approaches to Wave Phenomena in Plasmas," N. Marcuvitz, Polytechnic Institute of Brooklyn, N. Y.; 1/26/62.

"Electronics in Japan," E. C. Wolzien, National Bureau of Standards; 2/20/62.

DETROIT

"Pulse Compression in an Acoustic Waveguide," K. Walther, Bendix Research Labs.; 1/26/62.

"A Frequency Modulated Optical Communications System," J. Goodell and M. Tenberg, Westinghouse Electric Corp.; 3/30/62.

EMPORIUM

"Man's Conquest Over Information Through Electronics," D. G. Fink, Philco Scientific Labs.; 2/20/62.

"Infrared Reconnaissance Equipment for Terrain Thermal Mapping," D. E. Harris, Mgr. of Engr. Section, H.R.B.-Singer; 3/20/62.

EVANSVILLE-OWENSBORO

"Developments in the Application of Thermoelectricity," A. Cybriwsky, General Electric; 3/14/62.

FLORIDA WEST COAST

"Solid State Electronics—Past, Present and Future," C. L. Hogan, Motorola, Inc.; 3/23/62.

(Continued on page 110A)

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- Microwave Components
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In our commercial areas, a number of new opportunities have been created by expansion of such programs as: a 600 channel, fully transistorized and miniaturized multiplex telephone carrier system; a 600 channel microwave radio relay system (also fully transistorized) embodying a heterodyne repeater, parametric and traveling wave tube amplifiers; compact, transistorized two-way FM mobile radio; highly miniaturized personal communication equipment; tropospheric scatter equipment with modulation techniques, designed specifically for thin route applications.

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- Communication Equipment Advance Development
- Solid State Receiver Design
- 2-Way Mobile Transmitter Design
- 2-Way Mobile Systems & Reliability Engineering
- Military Sales Engineering
- Mobile Radio Sales Engineering

■ Your letter or resume will receive careful attention and a prompt, personal reply. Write in confidence to Mr. W. J. Kelly, Div. 53-MF, Communication Products Department, General Electric, Mountain View Road, Lynchburg, Virginia.

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Openings in Our Physical Research Department include:

Ph.D. in physics, with at least five years experience in semiconductor component research and development, a theoretical understanding of semi conductor (silicon and germanium) physics, research and development experience in the semiconductor device fabrication techniques such as diffusion, alloying, masking etching, and in particular be familiar with the epitaxial formation of multilayer semiconductor structures.

Assignment involves technical leadership for a program in molecular electronics which will first be concerned with the investigation and exploitation of the epitaxial technique to determine its limitation and capabilities as related to the fabrication of functional semiconductor structures.

Ph.D. in physical chemistry with three years of experience in the areas of electro-chemistry, preferably as applied to the formation of thin magnetic films. He should be familiar with the process of electro-deposition as related to magnetic materials and alloys, and have considerable understanding of magnetic theory, processes of crystal nucleation and growth as they are related to the formation of metallic electro-deposited films. It is also desirable to have technical familiarity with x-ray and electron diffraction examination and analysis methods, so that these skills may be brought to bear on the problem of the relationships of film composition and crystalline structure to the magnetic characteristics of electro-deposited films.

Ph.D. in physical chemistry, with approximately 5 years experience and theoretical understanding of the problems of materials preparation, structural and compositional analysis and interpretation, and methods of materials evaluation. Particular emphasis should include solid state materials, such as semiconductors, magnetic materials, superconductors, and dielectrics.

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Section Meetings

(Continued from page 108A)

FORT HUACHUCA

"Theory, Operation and Use of the SHORT PATH SONIC ANEMOMETER," H. R. Morgan, USAEPG; 3/27/62.

FORT WAYNE

"Lasers," G. B. Parrent, Jr., Technical Operations, Inc.; 4/5/62.

FORT WORTH

Student Papers Presentation; 3/1/62.

"Orientation to Digital Computers," P. H. Green, IBM Corp.; 3/6/62.

"Digital Computer Component Logic," J. R. Stumph, IBM Corp.; 3/13/62.

"Fundamentals of Programming and Programming Systems," R. J. Bell, IBM Corp.; 3/20/62.

FRANCE

Organization Meeting and Election of Officers; 1/30/62.

GAINESVILLE

"Theory and Application of Lasers," R. E. Johnson, Martin Co.; 1/10/62.

"Microminiaturization and Gas Discharge," D. Belknap, Diamond Ordnance Fuze Labs.; Joint with Florida University Student Section; 2/14/62.

"Biomedical Electronics," M. F. Eisenberg, University of Florida; 3/14/62.

HAMILTON

Tour of Aerovox Canada, Ltd., J. Lucyk; 3/12/62.

"Buyer-Seller Relationship," K. Revill, Philco Corp.; 4/9/62.

INDIANAPOLIS

"Micro-Miniaturization of Electronic Component Parts and Equipment," J. P. Morone, P. R. Mallory Co.; 3/22/62.

ITHACA

"Ion Propulsion," G. R. Brewer, Hughes Research Labs.; 3/21/62.

"Advanced in High Speed Transistors and Diodes," J. M. Early, Bell Tel. Labs.: 4/12/62.

KANSAS CITY

"Thermionics and Solid State Energy Conversion," J. R. Tudor, Univ. of Missouri; 3/13/62.

Tour of the Western Electric Facility, J. Kling, Asst. Superintendent of Engr.; 4/10/62.

KITCHENER-WATERLOO

"F.M. Stereo Multiplex," N. W. Parker, Motorola, Inc.: Joint with London Section; 3/12/62.

LAS VEGAS

"Engineering Needs in Education," C. A. Armstrong, Univ. of Nevada; 2/22/62.

"Nuclear Reactor Rocket Testing at NTS," J. H. Jurmain, Edgerton, Germeshausen & Grier, Inc.

"Neutronics Instrumentation for the Rover Program," R. Winn, Edgerton, Germeshausen & Grier, Inc.; 3/10/62.

LONDON-(CANADA)

"F.M. Stereo Multiplex," N. W. Parker· Motorola, Inc.; Joint with Kitchener-Waterloo Section: 3/12/62.

"Orbital Mechanics," D. J. Monroe, RCAF; 3/26/62.

(Continued on page 113A)

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NASA scientists and engineers work in many diversified fields. Included are: Fluid and Flight Mechanics, Energy and Power Systems, Materials and Structures, Space Sciences, Measurement and Control Systems, Data Systems, Experimental Facilities and Techniques, Life Sciences and Systems, and Program and Project Management, including supervision of the contracts. NASA invites your inquiry on the basis that you will be given opportunity that stretches your ability, wide choice of work area, tuition-free graduate study, if desired, while on full pay. You may direct your inquiry to any of the following NASA centers:

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NASA Launch Operations Center, Cocoa Beach, Florida; NASA Manned Spacecraft Center, Houston, Texas; NASA Goddard Space Flight Center, Greenbelt, Maryland; NASA Marshall Space Flight Center, Huntsville, Alabama; NASA Ames Research Center, Mountain View, California; NASA Flight Research Center, Edwards, California; NASA Langley Research Center, Hampton, Virginia; NASA Wallops Station, Wallops Island, Virginia; NASA Lewis Research Center, Cleveland, Ohio, or NASA Headquarters, Washington 25, D. C.

All qualified applicants will receive consideration for employment without regard to race, creed or color, or national origin. Positions are filled in accordance with Aero-Space Technology Announcement 252-B.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Section Meetings

(Continued from page 110A)

LOS ANGELES

Panel: "Planning Successful Product Lines," T. A. Kvaas, General Electric TEMPO, B. Angwin, General Electric Tube Div., R. B. Bonney, Electronic Engineering Co. of Calif.; Joint with Crescent Bay Subsection; 3/6/62.

LOUISVILLE

"Thermex 1.2 Megawatt Tube Tester," T. L. Wilson, Chemetron Corp., Electronic Section; C. Ellsworth, Project Engineer; R. Moore, Project Engineer; D. Frankel, Machlett Labs.; Joint with AIEE; 3/15/62.

"Contributions to Scientific Research from the Tracking of Artificial Satellites," K. E. Kissell, Aeronautical Research Lab., U.S.A.F. Base; Joint with AIEE & Louisville Astronomical Society; 3/30/62.

LUBBOCK

"A 3-Way Single Circuit Multivibrator," D. K. Ferry, Texas Tech College; "Positive Current Feedback," J. O. Pybus, Texas Tech College; Joint with AIEE; 3/12/62.

MIAMI

"Weather Bureau Flight Instrumentation & Data Analysis," A. C. Gruenfelder, U. S. Weather Bureau; H. W. Troutman, General Electric Co.; Tour of Weather Bureau aircraft, Flight facilities and Computer Center; 3/21/62.

MILWAUKEE

"Silicon Control Rectifiers and Circuits," J. Munganast, General Electric Co.; 3/6/62.

MOBILE

"Digital Computer Logic," D. Simmons, IBM Corp.; 11/17/61.

"Evolution of Nuclear Submarines," P. O'Keefe USN, Ingals Shipbuilding Corp.; 1/25/62.

"Seismology," L. J. Eisele, Springhill College; 2/15/62.

MONTREAL

"The Detection of Interplanetary Communications," J. E. Hayes, Canadian Broadcasting Corp.; 3/9/62.

"The Registering Accelerometer," B. G. Cameron, Aviation Electric; 3/14/62.

"F.M. Stereo Broadcasting," W. B. Morrison, RCA Victor; 4/11/62.

NEW ORLEANS

"Engineering Opportunities in the Saturn Missile Program," W. MacIntyre and M. A. Donovan, Jr., Chrysler Space Division, Michoud Ordnance Plant; 3/30/62.

NEW YORK

"The Outlook for Electronics," Panel Discussion, A. J. Catapano, Merrill, Lynch, Pierce, Fenner & Smith, Inc.; P. Clark, Bernham & Co.; P. Leserman, Leserman, Steinbach, Ltd.; R. Sellers, R. C. Sellers & Associates; 4/4/62.

NORTH CAROLINA

"Use of Semiconductors in Microwave Generation," D. W. Atchley, Jr., Microwave Associates, Inc.; 3/16/62.

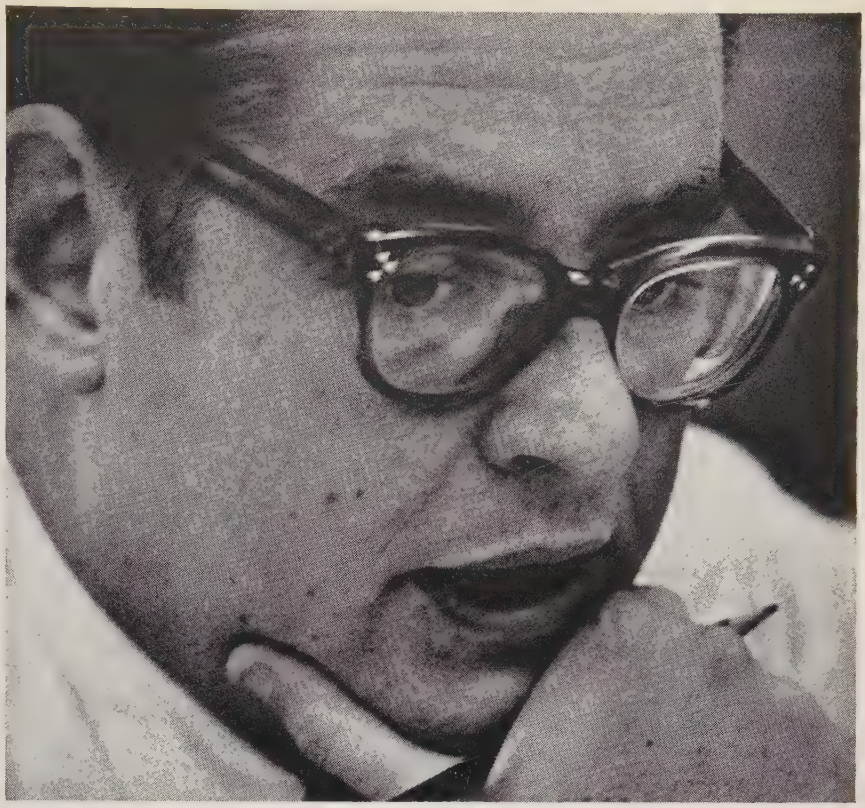
NORTHERN NEW JERSEY

"Radio Astronomy," E. A. Lilley, Harvard College Observatory; Tour of Space Communications Station at the ITT Labs.; 2/14/62.

"Information Science and the IRE, Past and Future," D. G. Fink, Philco Corp.; Annual Banquet, Dinner & Dance; 3/14/62.

(Continued on page 114A)

Northrop Space Laboratories needs impatient men



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Solid state physicists, to conduct fundamental research on many-body problems as applied to an ultra high pressure program. The goals of this program are to study the electrical and physical behavior of materials under ultra high pressure, to investigate the origin, history and structure of the moon and planets, and to find ways to utilize their natural resources.

Scientists, to perform research in nuclear and radiochemistry, and to conceive and carry out investigations in the fields of activation analysis, dosimetry, gamma ray spectrometry, surface phenomena, and numerous other areas.

Structural engineers, to do stress analysis and optimize the design of advanced space structures.

A plasma physicist, to join our growing program in the measurement of plasma properties, spectroscopy, diagnostics, accelerators, and power conversion devices.

A mathematician-physicist, to concentrate on systems analysis and operations research applied to military and non-military space systems.

Physicists experienced in electro-optical imaging devices and laser theory; **engineering mathematicians** interested in detection theory, reconnaissance and tracking; **electronic engineers** who know their way around statistical communications theory and noise phenomena; for new and original work in satellite detection systems.

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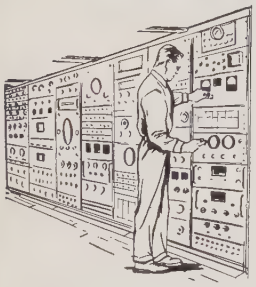

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Section Meetings

(Continued from page 113A)

NORTHWEST FLORIDA

"Instrumentation for Aerospace Probes," H. R. Dettwyler, Marquardt Corp.; 3/7/62.

"The Military and Scientific Potentials of Space," W. R. Dornberger, Bell Aerosystems Co.; Joint with Florida Post, American Ordnance Association; 3/19/62.

OKLAHOMA CITY

"Miniaturization of Electronic Circuits Using Thin Film Techniques," V. Shipman, Collins Radio Co.; Joint with AIEE; 2/27/62.

"Electronic Ignition Systems," R. Blizzard, Federal Aviation Agency Aeronautical Center; 3/12/62.

OMAHA-LINCOLN

"Applications of Stroboscopic Light," H. E. Edgerton, MIT; Joint With Neb. Section AIEE Comm. El. Tech. Group, and U. Neb. IRE-AIEE Student Branch; NOTE: Attendance at this 152nd meeting brings to over 10,000 the number of attendees at Omaha-Lincoln Section meetings, with an average attendance of 66 members, since the Section was established on September 9, 1948; 4/3/62.

OTTAWA

"Artificial Intelligence," G. S. Glinski, Ottawa University; "Instrumentation Magnetic Recording," E. L. Koller, Ampex of Canada, Ltd.; 3/1/62

"The Detection of Infrared Radiation," H. Pullan, RCA Victor Labs.; "Communications Systems," Dr. Von Bayer, Systems Engineering Group RCAF; 4/12/62.

Film "Again To The Stars,"—Titov Space Flight; Election of Officers; 4/18/62.

PHILADELPHIA

"Technological Unemployment," Mr. Larson and R. Bolz, U. S. Dept. of Labor; Joint with AIEE; 12/6/61.

PHOENIX

"The Latest Developments in the Field of High Power TWT's," J. T. Mendel, Hughes Aircraft Co.; 12/8/61.

"Circuits That Learn," J. Angell, Stanford University; 1/18/62.

"Confessions of a Psychologist"; 2/23/62.

"Advanced Antenna Systems," T. E. Tice, Motoroia, Inc.; 3/16/62.

PITTSBURGH

"Infrared Detection and Its Limits," M. Garbuny, Westinghouse Research Labs.; 3/5/62.

IRE Pittsburgh Section Student Paper Competition; 4/2/62.

PORTLAND

"Meson," L. Stevenson, Reed College; 11/29/61.

"Physiologic Consequences of Non-Linearities in the Nerve Membrane," G. Austin, Univ. of Oregon; 12/7/61.

"Graduate Center," H. Vollum, Tektronix, Inc.; 12/12/61.

"Melt Stock Cathode for Refractory Metal Melting," J. Griffith, Electro-Glass Labs.; 1/18/62.

"Graduate Program for the Portland Area," Dr. Millar, Portland State College; 2/22/62.

"Oregon State College Dad's Day," J. Griffith, Electro-Glass Labs.; G. Ebelseizer, Exact Electronics; D. Browning, Field Emission; S. Batori Controls Commission; 2/24/62.

"Masers," P. Perletti, Pacific Northwest Bell Telephone Co.; 3/1/62.

"Computers & Neurons," Dr. Tunturi, Univ. of Oregon; 3/8/62.

PRINCETON

"Project Mohole," H. H. Hess, Princeton University; 2/13/62.

"Electronic and Mathematical Approaches to Control Mechanisms in Living Cells," B. Chance, University of Pennsylvania; 4/10/62.

RIO DE JANEIRO

"Transit Satellite—Navigation (Satellite) Program," B. E. Hagler, U. S. Navy; 12/15/61.

Film "The 453 Steps—Transistors"—RCA Victor do Brasil; 2/14/62.

"The Navy Research Institute and the Brazilian Industry," J. C. B. Frederico, Brazilian Navy; 3/14/62.

ROME-UTICA

"Come North With Me," B. Balchen, General Precision Labs.; 2/21/62.

"Objectives of the Dept. of Defense Electronic Compatibility Center," B. Lindeman, Dept. of Defense; Joint with PGRFI; 3/13/62.

SACRAMENTO

"Tunnel Diodes," R. Davis, Chico State College; 3/22/62.

"Basic Color Television," D. Reahm, RCA Service Co.; 4/19/62.

SAN ANTONIO-AUSTIN

"Current Status of Molecular Electronics," C. R. Blankenship, Texas Instruments, Inc.; 1/26/62.

"Problems in Tropospheric Propagation and the Application of Radar Sounding," J. A. Saxton, The University of Texas; 2/15/62.

"The IRE and its Technical Future," L. V. Berkner, President, Graduate Research Center; 2/22/62.

"Bio-electrical Potentials," F. Harrison, Southwestern Medical School; 3/26/62.

SAN DIEGO

"Tracking of Ranger III By the Deep Space Instrumentation Facility," N. Renzetti, Jet Propulsion Lab., CIT; 3/7/62.

"IRE-AIEE Unification," C. R. Day, AIEE 8th District Vice-President; "IRE-AIEE Unification," D. K. Reynolds, IRE 7th Region Director; 4/4/62.

SCHENECTADY

"Future Air Traffic Control Systems," R. L. Biermann, Federal Aviation Agency; 3/20/62.

"Educational Television in the Capital District," W. J. Gold, Mohawk-Hudson Council on Educational Television; 4/17/62.

SHREVEPORT

"Radio Applications of Selective Signaling," D. W. Land, Motorola Communications & Electronics, Inc.; 2/6/62.

SOUTH CAROLINA

"Measuring Noise Through Noise," J. E. Sees, Univ. of South Carolina; 3/16/62.

"Low Loss Frequency Multipliers," C. Martin, Clemson College; 4/13/62.

TOLEDO

"Electronic Meters Digital and Analog, Their Properties, Specifications, and Uses," L. W. Elias, Sterling Co.; 1/9/62.

Tour aboard the Coast Guard Cutter Tupelo and demonstration of the Electronic Equipment, Lt. Foster; 3/15/62.

TORONTO

"Communications Satellites," Dr. Fitzwilliams, Bell Telephone Labs.; Joint with the Canadian Astronautical Society; 4/2/62.

TULSA

Student Papers, Joint with AIEE. 3/6/62.

(Continued on page 116A)

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Section Meetings

(Continued from page 115A)

VIRGINIA

"Exactly One Volt, Exactly One Ampere, Exactly One Ohm," C. H. Page, National Bureau of Standards; Tour of Norfolk Naval Shipyard; 3/9/62.

"Modern Trends in Electrical Engineering Education," G. R. Powley, Virginia Polytechnic Inst.; M. G. Foster, University of Virginia; 3/23/62.

"Scientific Methods of Crime Detection," I. W. Conrad, FBI; 4/6/62.

WASHINGTON

Discussion of IRE-AIEE Merger, B. J. Dasher, Georgia Tech.; Film on Gagarin Flight obtained from USSR Embassy; 11/13/61.

"Your Technology Is Not Enough," P. H. Robbins, National Society of Professional Engineers; 12/12/61.

"Learning Systems," E. B. Carne; Melpar, Inc., 1/8/62.

Annual Section Banquet; 2/10/62.

"The Use of Electronics In Modern Astronomy," F. J. Heyden, Georgetown Univ.; 2/19/62.

"NASA Space Communications Program," L. Jaffe, NASA; 3/16/62.

"Western European Advances In Electronics," G. Goudet, Laboratoire Centrale De Telecommunications; 3/19/62.

"Impact of Reliability on The Engineering Profession," L. W. Ball, The Boeing Co.; 4/10/62.

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WICHITA

"Measurement of Nuclear Radiation," W. R. Ford, Univ. of Wichita; 2/22/62.

"Instrumentation Problems in Speech Communications," H. Hollian, Institute of Logopedics; Tour of Inst. of Logopedics; 3/23/62.

"Dyna-Soar Guidance System," J. Bailey, Minneapolis Honeywell; Joint with AIEE; 4/4/62.

WINNIPEG

Tour of Bristol Aero Industries, Ltd., A. W. Fia; 3/15/62.

Annual Meeting; 4/6/62.

SUBSECTIONS

BUENAVENTURA

"Hyperbolic Systems as Navigational Aids," L. C. Read, Pacific Missile Range, Point Mugu; 3/14/62.

"The Laser-Physics, Properties and Future," D. A. Buddenhage, Hughes Research Labs.; 4/11/62.

CRESCENT BAY

"Product Planning," Panel Discussion; Joint with Los Angeles Section; 3/6/62.

EAST BAY

"European Adventures in Television," J. Roizen, Ampex Corp.; 1/22/62.

FAIRFIELD COUNTY

"New Telephone and Data Communications Services," P. N. Johnstone, Southern New England Telephone Co.; Tour of facilities; 4/5/62.

LANCASTER

"Nuclear Radiation Detectors," G. A. Morton, RCA Labs.; 2/27/62.

MEMPHIS

"Video Tape," Mr. Frase, WMC-TV NBC outlet; 3/20/62.

MERRIMACK VALLEY

"The Revolution in High School Science," E. Hoffart, Staff member of Education Services, Inc. and the PSSC; 2/12/62.

"Bell System Communications Systems—Present and Future," U. S. Berger, Bell Telephone Labs., Inc.; 3/19/62.

MONMOUTH

"Electronic Organs," R. H. Dorf, Schober Organ Co.; 2/21/62.

NORTHERN VERMONT

"Education in Russia and America," J. Bohuslaw, General Electric Co.; 3/19/62.

ORANGE BELT

"High Density Packaging," H. F. Sawyer, General Dynamics; Joint meeting with the Student Branch of California State Polytechnic College; 1/17/62.

"Image Storage in Information Retrieval," L. D. Stevens, IBM Corp.; Joint meeting with Los Angeles Section; 2/13/62.

"A Reappraisal of Strip Transmission Line," S. Cohn, Rantec Corp.; 3/21/62.

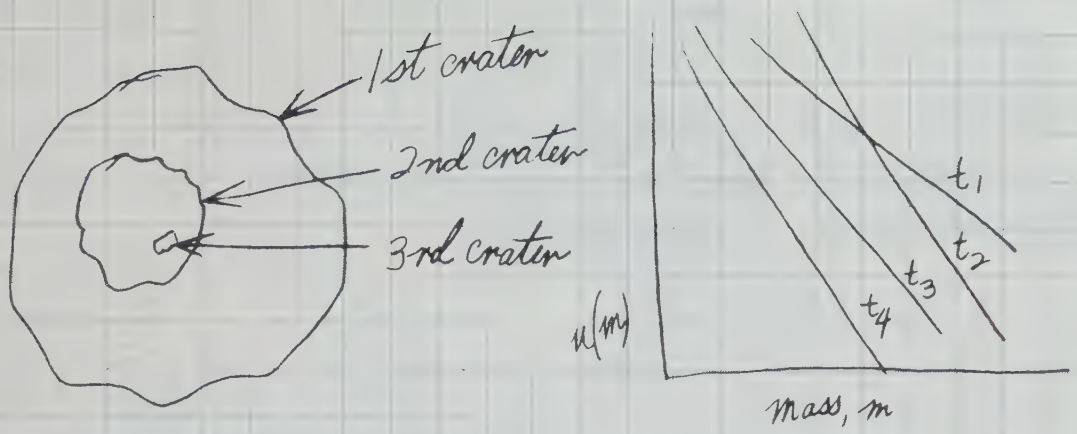
PASADENA

"Operational Design Aspects, Weather Satellite System," M. G. H. Ligda, Stanford Research Institute; 3/15/62.

RICHLAND

"The Algebra of Four-State Safety Devices," A. D. Wiggins, Hanford Labs., General Electric Co.; Joint with AIEE; 2/28/62.

(Continued on page 118A)



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Section Meetings

(Continued from page 116A)

"Silicon Diodes for Alpha Counting and Energy Analysis," R. E. Connally and E. M. Sheen, General Electric Co.; 3/28/62.

SANTA ANA

"Information Science and the IRE—PAST and FUTURE," D. G. Fink, Research Div., Philco Corp.; 3/20/62.

SANTA BARBARA

Tour of General Motors, Santa Barbara Facility; 3/14/62.

"Weapon Effects & Civil Defense," H. Borella, Edgerton, Germeshausen & Grier; 4/17/62.

SOUTHWESTERN ONTARIO

General Membership Meeting; 2/22/62.

VICTORIA

"Work Measurement and Method Analysis," A. M. Baxter and W. R. Brain; Navy; 1/17/62.

WESTERN NORTH CAROLINA

"Eastern Airlines Computer Reservations Facility," F. C. Herdje, Eastern Airlines; Tour of Eastern Airlines Computer Reservations Facility; 1/26/62.

"Space Communications by Satellites," C. B. Mehaffey, Charlotte Dist. Manager; 2/23/62.

"Parametric Amplifiers," F. Thompson and D S. Avera, Jr., Western Electric Co.; 3/23/62.

Professional Group Meetings

ANTENNAS AND PROPAGATION

Akron—November 29

"Review of the 11th Annual Symposium on the USAF Antenna Research and Development Program," G. H. Welch, Goodyear Aircraft, Akron.

San Francisco—January 10

"Backward Wave Antennas," P. E. Mayes, University of Illinois—presently on Sabbatical Leave at University of California.

ANTENNAS AND PROPAGATION MICROWAVE THEORY AND TECHNIQUES

Baltimore—March 14

"Microwave Plasma Diagnostics," Dr. M. Heald, Swarthmore College.

San Francisco—February 21

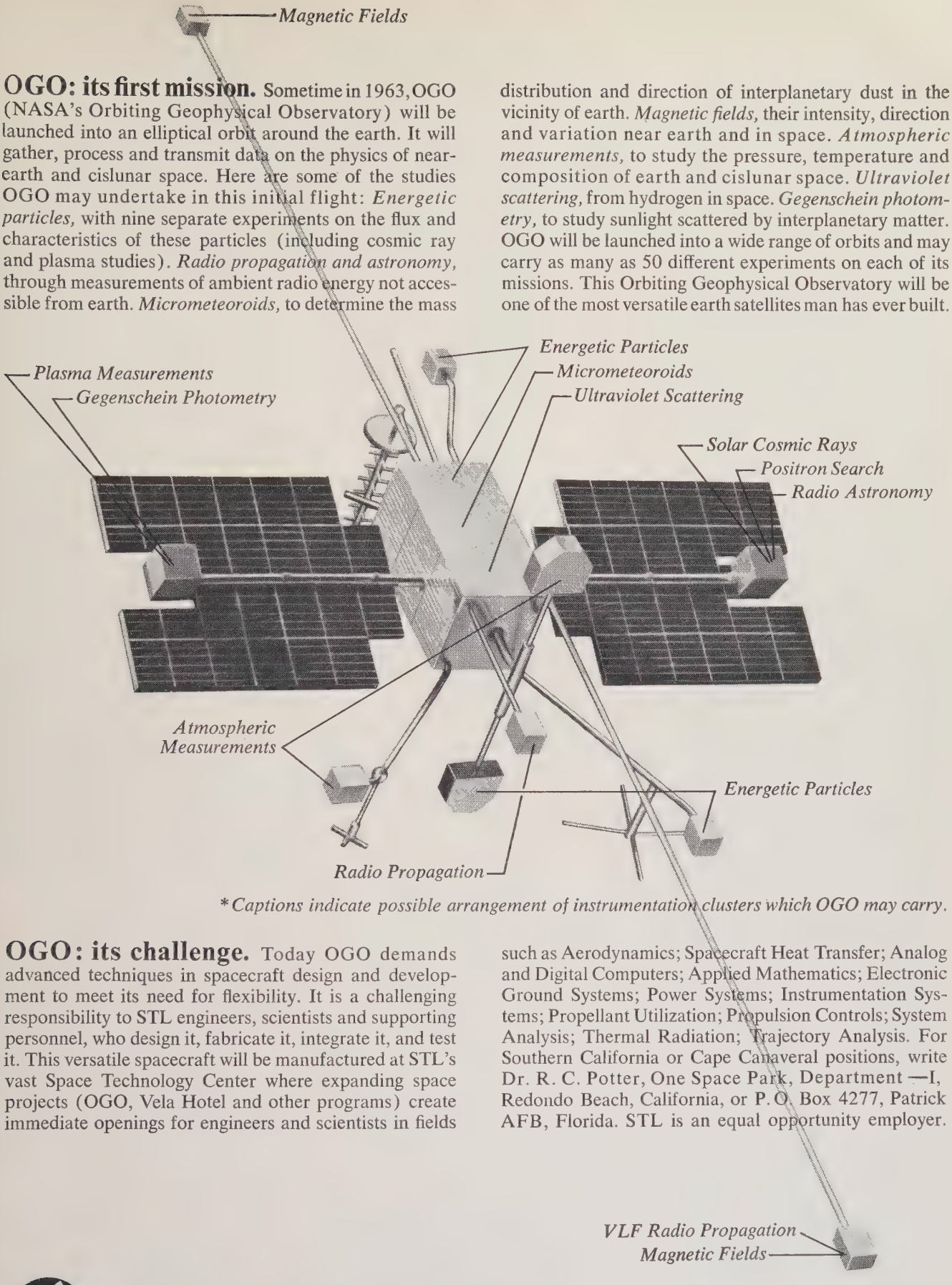
"Millimeter Propagation," Prof. A. Straiton, University of Texas.

San Francisco—February 14

"Generation of Power at Millimeter Wavelengths," W. Teich and J. Skowron, Raytheon Spencer Lab.

(Continued on page 120A)

OGO: its first mission. Sometime in 1963, OGO (NASA's Orbiting Geophysical Observatory) will be launched into an elliptical orbit around the earth. It will gather, process and transmit data on the physics of near-earth and cislunar space. Here are some of the studies OGO may undertake in this initial flight: *Energetic particles,* with nine separate experiments on the flux and characteristics of these particles (including cosmic ray and plasma studies). *Radio propagation and astronomy,* through measurements of ambient radio energy not accessible from earth. *Micrometeoroids,* to determine the mass distribution and direction of interplanetary dust in the vicinity of earth. *Magnetic fields,* their intensity, direction and variation near earth and in space. *Atmospheric measurements,* to study the pressure, temperature and composition of earth and cislunar space. *Ultraviolet scattering,* from hydrogen in space. *Gegenschein photometry,* to study sunlight scattered by interplanetary matter. OGO will be launched into a wide range of orbits and may carry as many as 50 different experiments on each of its missions. This Orbiting Geophysical Observatory will be one of the most versatile earth satellites man has ever built.



** Captions indicate possible arrangement of instrumentation clusters which OGO may carry.*

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Professional Group Meetings

(Continued from page 118A)

Audio

Chicago—March 9

"High Fidelity—Where Do We Go From Here?"

Panel discussion: Moderator, K. Kramer, Jensen Mfg. Co.

Panel members: D. Schory, RCA Victor; A. B. Clapper, Universal Recording Studios; G. Lang, W. G. N.; and R. P. Glover, Jensen Mfg. Co.

Chicago—February 21

"Novel Stereo Recording Techniques," D. Schorey, RCA Victor.

Philadelphia—February 2

"Diffraction Studies Using Temple's New Anechoic Chamber," Dr. M. Harbold, B. Steinberg, Temple University, Philadelphia, Pa.

Other activities: Tour of Barton Hall, Demonstration of Planetarium, Plasma Studies, Wire Explosion experiment, and visit to Micrometeorite Detector Studies Lab.

San Antonio-Austin—March 23

"Audio Semi-Conductor Circuits," D. Meyer, Southwest Research Inst., San Antonio.

Audio/Broadcasting Broadcast and Television Receivers

Philadelphia—March 2

"Transistorized Video Tape Recorder TR-22," R. N. Hurst, A. C. Luther, RCA, Camden.

Slide Show accompanying lecture.

Automatic Control

Dallas-Fort Worth—February 27

"Manned Aerospace Flight Simulator," W. T. Luton, Vought Astronautics, Grand Prairie, Tex.

Los Angeles—February 13

"A Survey of Optimal Control," R. Nesbit, Aerospace Corp., Los Angeles.

Los Angeles—January 9

"Ballistic and Lifting Re-Entry Guidance and Control," Capt. E. Volgenau, Air Force Space Systems Div., Los Angeles.

Philadelphia—February 27

Automatic Control of Aircraft and Space Vehicles," J. Cavanagh, General Electric Co.

(Continued on page 122A)

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BSEE — Elec. Eng. — 3 yrs. exp. Command Control Systems (CR)

BSEE — Elec. Eng. — 3 yrs. exp. Radar Beacon Work (CR)

BSEE — Elec. Eng. — 3 yrs. exp. Television Transmission (CR)

BSEE — GSE Supervisor — 5 yrs. exp. Equipment Development (CR)

BSEE — GSE Eng. — 3 yrs. exp. Ground Support (CR)

SYSTEMS

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MSEE or equiv. — System Analyst — 5 yrs. exp. Tracking and Ranging (CR)

MSEE — System Analyst — 5 yrs. exp. Communications (CR)

BSEE minimum — GSE Integration Supervisor — 5 yrs. exp. Ground Support (CR)

MS or equiv. in Physics or Mechanics — System Analyst — 3 yrs. exp Classical or Celestial (CR)

BS — Field Supervisor — 5-10 yrs exp. Airborne Electronics and Communications (CR)

BS or equiv. in EE — Field Eng. — 3-5 yrs. exp. Com. (CR)

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BSME or equiv — Mech. Eng. — 3-5 yrs. exp Packaging Designs (CR)

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BSEE — Elec. Eng. — 3-5 yrs. exp. Microwave Systems (D)

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GENERAL

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BSEE — desirable — Logistics Eng. — 2-3 yrs. exp. Space Program Logistics (CR)

BSEE desirable — Logistics Supervisor — 3-5 yrs. exp. Space Program Logistics (CR)

BSEE or higher — R&D Eng. — 1-5 yrs. exp. Antenna Systems (D)

BSEE — Elec. Eng. — 1-5 yrs. exp. Design Review and Prediction (D)

BSEE — Project Test Eng. — 1-5 yrs. exp. Quality Assurance (D)

BSEE — Telephone Eng. — 4-7 yrs. exp. Central Office (D)

ME or IE — Staff Eng. — 2 yrs. exp. in MTM (D)

DATA

BSEE or higher — Senior Staff Asst. — 8-10 yrs. exp. Digital (CR)

MS or PhD — Applied Math — 10 yrs. exp. Business Computing (CR)

BSEE — Elec. Eng. — 5-8 yrs. exp. Digital Data Design (D)

Applied Math — Computer Programmer — hvy. exp. with Large Computers (D)

Applied Math — Business Programmer — ext. exp. Business Data Processing (D)

Applied Math — Scientific Programmer — ext. exp. Scientific Data Programs (D)

Math PhD — Logic Program Designer — ext. exp. Planning, Preparing Programs (D)

PLEASE NOTE

On listings marked (CR), send resume to L. R. NUSS, COLLINS RADIO COMPANY, CEDAR RAPIDS, IOWA

On listings marked (D), send resume to C. P. NELSON, COLLINS RADIO COMPANY, DALLAS, TEXAS

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IBM is an Equal Opportunity Employer.
Please write, outlining your background and interests: Fred Guth, Dept. 645S, IBM Space Guidance Center, Owego, New York.
IBM

Professional Group Meetings

(Continued from page 120A)

Philadelphia—January 9

"The Use of Digital Computers in Process Control in the Steel Industry," R. W. Sonenfeld, RCA.

Philadelphia—November 21

"Controlled Nuclear Power Plants," J. M. Finan, Leeds and Northrup Co., North Wales, Pa.

Bio-Medical Electronics

Buffalo—February 20

"X-Ray Image Intensifiers, Construction, Evaluation and Applications," A. Lignon, North American Phillips Co., New York, N. Y.

San Francisco—February 20

"Sensory Deprivation and Instrumentation Research," J. K. Dupress, American Foundation for the Blind, New York, N.Y.

Broadcasting

Houston—December 12

"Weather Radar," L. Patillo, PRC TV Houston.

Circuit Theory

Albuquerque-Los Alamos—March 19

"Fundamentals of Non-Linear Systems—Part 2," Dr. W. W. Koepsel, University of New Mexico.

Philadelphia—March 21

"Bandpass Filtering with Lowpass Filters," H. Urkowitz, Philco Corp., Blue Bell, Pa.

Communications Systems

Toronto—March 12

"Information Theory in Communications," R. N. E. Haughton, Bell Telephone Co. of Canada.

Component Parts

Los Angeles—March 12

"Darnell Report, Implementation of," H. Mottley, Air Force Ballistic Missiles.

Philadelphia—January 23

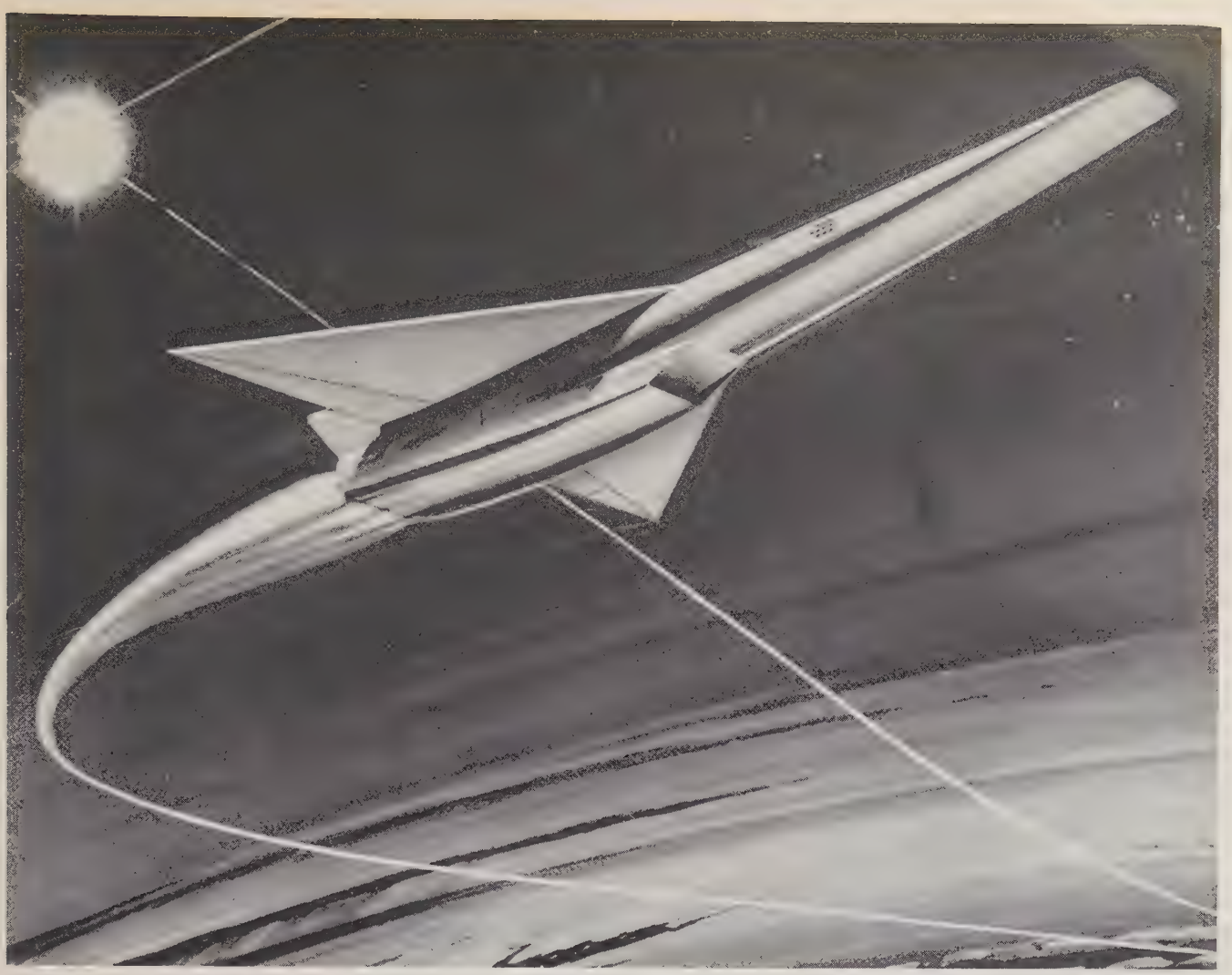
"Component Parts for Space Environments," S. N. Iehr, Space Technology Labs., Los Angeles.

Philadelphia—December 12

"High Reliability—A Businessman's Viewpoint," A. E. Peltosalo, General Electric, Irmo, S. C.

"Minuteman Solid and Foil Tantalum Capacitor Programs," W. H. Roberts, General Electric, Irmo, S. C.

(Continued on page 124A)



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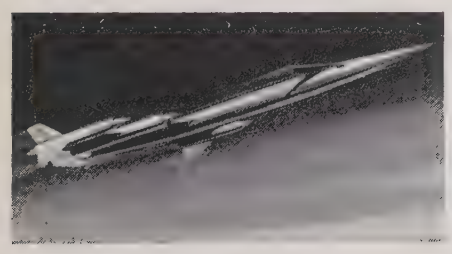

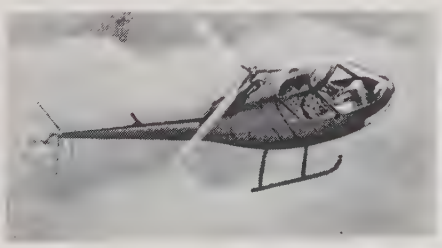

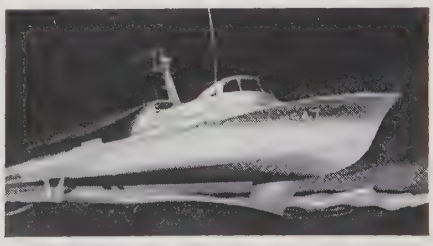

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AEROSPACE DIVISION
MINUTEMAN DIVISION
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Operational reliability analysis to define and allocate reliability goals. Construct system models, perform design review and evaluate reliability test programs.

AEROSPACE DEVICES
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COMPONENTS AND PARTS
Selection and failure analysis of parts. Component inspection, test criteria, vendor evaluation.

STATISTICAL METHODS
To develop and apply statistics to reliability and quality control analysis including prediction and measurement, test design and analysis system synthesis and trade off models.

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Professional Group Meetings

(Continued from page 122A)

Component Parts/Electron Devices

Omaha-Lincoln—March 15

"Development in Unusual Power Generation—With Demonstration of Fuel Coll, Gas Fired Radio and Fan, and Flameless Gas Heater," M. L. Lead, Northern Natural Gas Co., Omaha.

Component Parts/Electron Devices/Reliability and Quality Control

Los Angeles—December 5

"System Reliability in Space," C. M. Ryerson, Altec.

"The Insufficiencies of Reliability Tech," P. A. Adamson, Hughes Aircraft Co.

"Elements of Reliability of Space Vehicles," Dr. L. Aroian, STL.

"Space Testing of Ion Engines," R. S. Tom, Electro-Optical Systems, Inc.

"Semiconductor Electronic Design for Reliability," J. Bluie, Pacific Semiconductors, Inc.

"The Importance of Reliability in Space Exploration," Dr. F. Goddard, JPL.

"Nuclear Radiation Problems with Electronic Components," Dr. Wiser, Hughes Aircraft Co.

"Performance of Flexible Organic Cable in Space Environment," P. M. Cook, Raychem Corp.

"Reliability of Solar Arrays," W. A. Klein, STL.

"Welding of Electronic Modules for Space Environments," J. Gates, Welded Electronic Modules.

Electron Computers

Akron—December 7

"Microminiature Components for Space Electronics," S. M. Stuhlbarg and A. Smith, P. R. Mallory, Inc., Indianapolis.

Akron—November 21

"Error Control in Real Time Digital Computer Applications," G. M. Griffith, Remington Rand, St. Paul.

Detroit—January 23

"Recent Developments in Thin Film Memories," R. J. Petschauer, Remington Rand Univac, St. Paul, Minn.

Santa Ana—February 22

"Tunnel Diodes," S. Marcy, RCA.

"Cryogenic Devices," J. Rogers, STL.

"Transistor Devices," G. Goldstick, NCR.

(Continued on page 125A)

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A new program has started in the development of Integrated Circuits for computers and business machines. Circuits both in thin films and in semiconductor blocks will be designed, made, and evaluated. Novel circuits, applications, and processes will be sought. This program will provide growth opportunities along technical or managerial lines for imaginative experienced individuals. Backgrounds are desired in thin films, semiconductors, or logic design. Specific openings comprise:

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- **ELECTRONICS**
  To design and evaluate integrated circuits
- **LOGIC**
  To specify and evaluate integrated circuits in logical applications
- **PROCESS**
  To establish and improve processes in thin film and semiconductor technology such as evaporation, diffusion, contacting, surface treatment, epitaxy, etc.

In addition to unexcelled facilities and opportunities, NCR offers many unusual and unexpected benefits both in living and working climate. Purposeful effort, long range planning, and good management backed with 78 years of systems experience underlie the stimulating program of research and development now emerging at NCR. To be considered for what may be your ground floor opportunity, write to:

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Professional Group Meetings

(Continued from page 124A)

Engineering Management

Los Angeles—February 22

"The Consulting Engineer—His Fit, Function and Future," D. Lebell, Don Lebell Assoc.

Engineering Writing and Speech

San Francisco—February 20

"Making Visual Aids Effective," R. Sims and A. Cassingham, Sylvania, Mountain View, Calif.

Information Theory

Baltimore—March 7

"The Statistical Theory of Signal Detection," Dr. C. W. Helstrom, Westinghouse Res. Labs., Pittsburgh.

San Francisco—February 8

"Receivers for Randomly Varying Channels," Dr. T. Kailath, Jet Prop. Lab., California Inst. of Tech.

Instrumentation

Philadelphia—February 12

"The Application of Elementary Statistics to Measurement," Dr. K. W. Goff, Leeds and Northrup, Philadelphia.

Washington, D.C.—March 5

"Spacecraft Instrumentation for Studies of Upper Atmosphere," R. E. Bourdeau, GSFC, Greenbelt, Md.

Microwave Theory and Techniques

Northern New Jersey—February 23

"Phased Arrays," A. Brockway, Bendix, Towson, Md.

Orlando—February 23

"Some Potentialities of Optical Masers," Dr. B. M. Oliver, Hewlett-Packard Co., Palo Alto.

Military Electronics

Baltimore—November 24

"Photoconductors in Electro Optical Systems," Dr. Z. P. Szepesi, Westinghouse, Elmira, N. Y.

Detroit—February 15

"The Design of Lunar Vehicles," G. M. Jordan, Bendix Systems Div., Ann Arbor, Mich.

(Continued on page 126A)

Melpar's new AEROSPACE PROGRAMS

Have Created Additional Positions for SCIENTISTS and ENGINEERS in the

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APPLIED SCIENCE DIVISION

The work assignments require advanced training and experience in:

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- Programming of Intergro-differential Equations
- Pharmacology
- Microelectronics
- Infrared Technology
- Antenna Systems • Thin Films
- Operations Research • Space Communications
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- System Reliability

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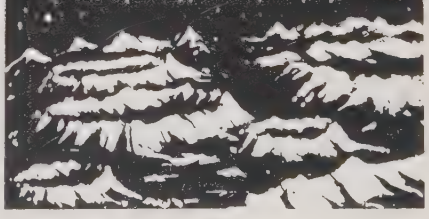

RESEARCH ENGINEERS AND SCIENTISTS

ADAPTIVE PATTERN RECOGNITION... A system conceived by Sheldon Akers and associates at the Electronics Laboratory adaptively organizes its internal logic circuits as it is fed binary samples of a pattern in its various forms. The letter "A" for instance may be large, small, rotated, translated, with and without serifs, etc. • Through a prescribed algorithm, the adaptive system ultimately establishes a network of threshold logic gates capable of recognizing the pattern in whatever form it appears. Simulation has been accomplished by means of a computer program. Several pattern recognition trials have been run with results that far surpass those of random—or heuristic—recognition networks.

Can You Define Boundaries for Electronics ?

• Investigators at General Electric's Electronics Laboratory believe that no technology is so "remote" that it may not one day contribute to advances in one of the diverse areas conveniently labeled "electronics" today. The result of this philosophy is an enriching collaboration among individuals from many fields. The above abstract indicates one of the many areas of interest under investigation by staff members. Scientists and engineers (with PHD, MS, or BS degrees) attracted by a multidisciplinary intellectual climate, are invited to inquire about *opportunities to explore new approaches to:*

SOLID STATE DEVICES. MICROELECTRONIC CIRCUITRY. ELECTRONICALLY FUNCTIONAL THIN FILMS. DATA PROCESSING TECHNIQUES USING THEORIES OF AUTOMATA, ADAPTIVE SYSTEMS. PHYSICAL PHENOMENA WITH POTENTIAL FOR MICROWAVE AND COHERENT OPTICAL DEVICES. NON LINEAR AND ADAPTIVE CONTROL SYSTEMS. MATERIALS AND PROCESSES (INORGANIC & ORGANIC CHEMISTRY) • *Write in confidence to:* Mr. Richard J. Sullivan, Dept. 53F, General Electric's Electronics Laboratory, Electronics Park, Syracuse, New York.

ELECTRONICS LABORATORY

GENERAL ELECTRIC

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Professional Group Meetings

(Continued from page 125A)

San Francisco—February 6

"The Use of Program Evaluation Review Techniques (PERT) on Small Military Projects," J. L. Holcomb, Varian Associates, Palo Alto.

Nuclear Science

Los Angeles—February 20

"Advances in Solid State Ionization Chambers," Dr. S. S. Friedland, Solid State Radiation, Inc., Los Angeles.

Product Engineering and Production

Boston—March 13

"The Mechanical Engineer in Electronics," J. C. French, Raytheon Co., Wayland, Mass.

San Francisco—January 23

"Operation of Milwaukee-Matic Milling Machine," A. Watts and H. Hampel, Hewlett-Packard Co., Palo Alto.

Radio Frequency Interference

Los Angeles—January 18

"Commentary and Film 'Electromagnetic Interference Ashore'," D. Clark, USN Civil Engineering Lab.

"Trends in RFI Instrumentation," R. R. Stoddart, Stoddart Aircraft Radio Co.

Reliability and Quality Control

Boston—February 15

"Systems Effectiveness Models," G. E. O'Rourke, Jr., and M. H. Blitz, Sylvania, Waltham.

"Extension of the PERT Technique into System Reliability Management," R. W. Miller, Raytheon, Waltham.

Los Angeles—February 19

"Reliability System Test Plans," M. Saltz, Hughes, Culver City.

"Component Reliability Testing," S. L. Webster, Hughes, Culver City.

"Reliability through Environmental Testing," R. L. Baker, Hughes, Culver City.

Reliability and Quality Control/Space Electronics and Telemetry

Los Angeles—January 15

"Reliability of Long Range Communications in Space," Dr. N. A. Renzett, Jet Prop. Lab., Cal. Tech.

"Extreme Environment Space Communications System," P. Gluth, Aeronutronic, Newport Beach.

(Continued on page 128A)

Vitro starts ADVANCED DEVELOPMENT SECTION

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- **offers unique ground-floor opportunities to Sr. Engineers and Physicists**

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The men we seek for analytical and theoretical work should have at least a B.S. in electronics or physics and considerable background in mathematics as applied in communication theory, information theory, and modulation theory. Product development positions require original circuit experience in solid state techniques and components including parametrics, transistors, etc., and digital techniques. Equipment range up to 10k mc.

Our facilities are located in Silver Spring, Maryland, a residential suburb of Washington, D. C., affording you a choice of country, suburban or city living. Public schools are excellent, and five nearby universities offer graduate courses. The cultural pleasures of the Nation's Capital are just minutes away, and the countryside provides every opportunity for sports, from mountain climbing to boating and fishing on the Chesapeake Bay.

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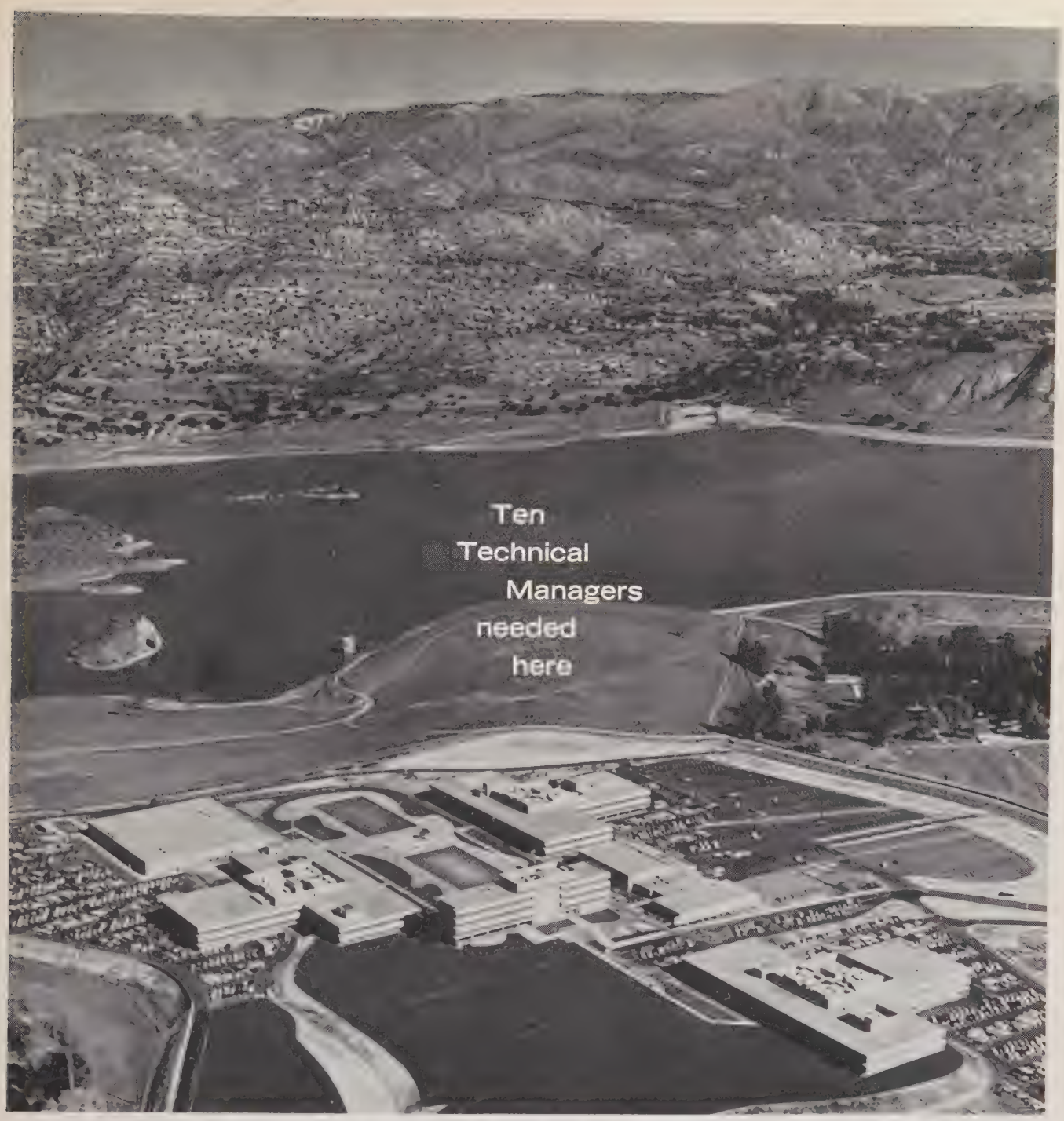

This is the RW Division of Thompson Ramo Wooldridge Inc., at Canoga Park, California. RW is expanding in various fields of computer-related technology: design and building of computers, display devices and information systems under contracts with the Army, the Navy, the Air Force, the Defense Atomic Support Agency and to industry. As RW grows, so must its staff. If you have experience at the project engineer level in military data processing, range instrumentation, automatic checkout systems, fire control systems, or tactical weapons control centers, we'd like to talk to you about one of ten technical management positions now open. A number of other positions in computer development and programming are also open. Write to Robert Rogers, RW Division, Thompson Ramo Wooldridge Inc., 8433 Fallbrook Avenue, Canoga Park, California. Geographical note: Canoga Park is in Southern California's San Fernando Valley; over the mountains lies Malibu and the sea. You may live conveniently in either place.

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Research and Development
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Massachusetts Institute of Technology
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Professional Group Meetings

(Continued from page 126A)

Space Electronics and Telemetry

Detroit—January 26

"Sources and Characteristics of Sound at High Altitudes," J. W. Wescott, University of Michigan.

Detroit—November 29

"Instrumentation Applications of Wide Band Tape Recorders," R. E. Shrader, Ampex Instrumentation Products.

Other activities: Tour of WWJ-TV Studios.

Philadelphia—February 27

"Automatic Control of Aircraft and Space Vehicles," J. Cavanagh, General Electric Co., King of Prussia, Pa.

Philadelphia—January 17

"Nimbus Satellite System," Dr. R. Stampfl, N.A.S.A. Goddard Space Flight Center.

Philadelphia—November 5

"High Reliability Receiver Design for Satellites," H. Gruen and M. Levin, Philco Corp., Philadelphia.

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Philadelphia—October 10

"Adaptive Digital Communication System for a Slowly Varying Channel," G. Lieberman, RCA, Camden, N. Y.

San Francisco—February 20

"Space and Ground Antenna," Dr. P. Kennedy and R. Trainer, Lockheed, Sunnyvale, Calif.

Vehicular Communications

Chicago—January 25

"Personal Signalling," R. E. Sefton, Illinois Bell Telephone Co.

Detroit—January 24

"Antenna Systems Problems and Measurements," S. Shanken, Antenna Specialists Co., Cleveland, Ohio.

Membership

The following transfers and admissions have been approved and are now effective:

Transfer to Senior Member

Allen, U. L., Jr., Silver Spring, Md.
Bailey, B. H., Jr., Natchitoches, La.
Bell, R. L., Palo Alto, Calif.
Bernstein, J. L., Westbury, L. I., N. Y.
Bondy M., Chatham, N. J.
Burr, H., Dearborn, Mich.
Carne, E. B., McLean, Va.
Carpenter, H. E., Jr., University Park, Md.
Cheng, H-S, Dearborn, Mich.
Collier, A. F., Rochester, Mich.
Dombrowski G. E., Storrs, Conn.
Duggan, R. S., Jr., Atlanta, Ga.
Edwards, A., Jr., Briarcliff Manor, N. Y.
Frei E. H., Rehovoth, Israel
Garlan, H., Annandale, Va.
Gentry, C. T., Dover, N. J.
George, E. P., Sunnyvale, Calif.
Giaimo, E. C., Jr., Princeton, N. J.
Goldwag, H., Fairfax, Va.
Goodwin, P. H., Jr., Corona Del Mar, Calif.
Gostyn, E., Longmeadow, Mass.
Haase, K. H., Watertown, Mass.
Harrington, R. F., Syracuse, N. Y.
Hayashi, M., Seattle, Wash.
Hirsch, H. R., Bethesda, Md.
Howard, D. C., Jr., Melbourne, Fla.
Jeffs, C. R., Santa Monica, Calif.
Kluck, J. H., La Jolla, Calif.
Krasney, S., Haddonfield, N. J.
Lambert, R. F., Minneapolis, Minn.
Lebel, J. D., Paris, France
Liss, F. T., Bethesda, Md.
Lockhart, R. J., Holloman AFB, N. M.
Lommasson, T. E., Albuquerque, N. M.
Lowenberg, E. C., Austin, Tex.
Lowther, F. E., No. Syracuse, N. Y.
Manoog, J. C., Worcester, Mass.
Margolin, J., Cambridge, Mass.
Marinace, J. C., Yorktown Heights, N. Y.
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Matejka, J., Omaha, Neb.
McEwan, A. J., Washington, D. C.
Michaels, C. J., Jr., Berwyn, Pa.
Muir, W. A., Bellevue, Neb.
Meyer, H. R., Fullerton, Calif.
Neill, G. W., East Hartland, Conn.
Neudorfer, W. L., Canoga Park, Calif.
Ochoa, S. A., Bogota, Colombia, S. A.
Orr, R. V., Baltimore, Md.

(Continued on page 130A)

GENERAL DYNAMICS | ELECTRONICS ROCHESTER

POSITIONS OPEN IN

ELECTRONIC RECONNAISSANCE SYSTEMS

SENIOR ANTENNA ENGINEER

BSEE with 3 to 4 years experience on ground-based antennas and radomes. Knowledge of antenna test data reduction and analysis required. Frequency spectrum VHF and up. To design systems antenna configurations, analyze existing designs, reduce and analyze antenna test data and make recommendations for necessary re-design.

SENIOR RELIABILITY ENGINEER

BSEE with 3 to 5 years experience. Must be systems oriented in the reliability field, preferably with some operations research background. Will be responsible for designing and implementing a reliability program on a large electronic system and will make the necessary data reduction involved in such a program.

SENIOR DESIGN ENGINEERS

BS with 8 years experience, of which 5 must have been in design in two or more of the following: digital, RF, pulse, audio, CRT, photorecorders, magnetic recorders, pulse multiplex and frequency multiplex. To assist in evaluation of complex electronic reconnaissance systems.

DESIGN ENGINEERS

BS with 3 to 5 years experience in RF and microwave receivers, digital display circuits, data handling and CRT displays including storage tube circuits. To assist in evaluation of complex electronic reconnaissance systems.

HYDROACOUSTICS

SENIOR SONICS ENGINEER

BS or MS in ME or Physics with at least 5 years experience in Industrial Sonics. Should have background in sonic cleaning, processing and impact drilling plus a basic knowledge of acoustics, general physics and chemistry.

TEST EQUIPMENT & INSTALLATIONS

PROJECT ENGINEERS

To supervise design and integration of test stations. Knowledge should include 1 or more of the following areas: flight control systems, radar indicators, HF-VHF navigation and communication equipment, microwave equipment, antenna systems and ECM. Should be familiar with all types of testing techniques and equipment associated with particular areas of interest. BSEE.

SENIOR DESIGN ENGINEERS

BSEE with thorough background in one of the following: microwave signal generators and receivers; low frequency signal generators, HF-UHF signal generators, digital and pulse circuits, AGE Systems.

TECHNICAL WRITING

Requires thorough background in the electronics industry in preparation of military handbooks and manuals or in engineering proposals.

RECONNAISSANCE EQUIPMENT DESIGN

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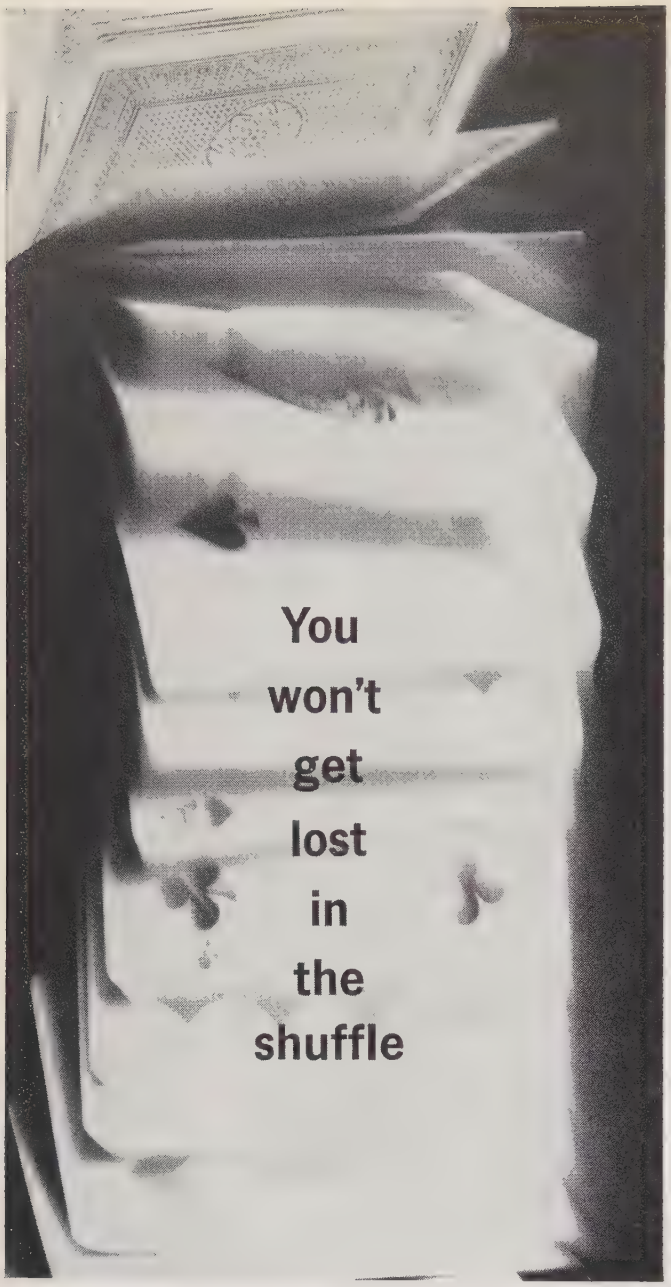

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Peak Rectified Current		150 mA
Surge Current for 1 Second		500 mA
Ambient Temperature Range	−60 to +90	°C
Power Dissipation		80 mW
Maximum Forward Voltage @ 100 mA		1 V

Electrical Rating Code (ordering)	Degree of Forward Match @ 4 mA	PIV each Diode	Maximum Inverse Current @ −10 V
1	1%	35 V	20 μa
2	1%	75 V	10 μa
3	1%	100 V	10 μa
4	2.5%	35 V	20 μa
5	2.5%	75 V	10 μa
6	2.5%	100 V	10 μa
7	5%	35 V	20 μa
8	5%	75 V	10 μa
9	5%	100 V	10 μa

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Surge Current for 1 Second		1.5 A
Ambient Temperature Range	−60 to +150	°C
Power Dissipation		250 mW
Maximum Forward Voltage @ 100 mA		1 V
Maximum Reverse Current @ PIV		.025 μa
Maximum Reverse Current @ PIV (150°C)		5.0 μa

Electrical Rating Code (ordering)	Degree of Forward Match @ 4 mA	PIV each Diode
1	.5%	25 V
2	.5%	125 V
3	.5%	180 V
4	1.0%	25 V
5	1.0%	125 V
6	1.0%	180 V
7	2.5%	25 V
8	2.5%	125 V
9	2.5%	180 V

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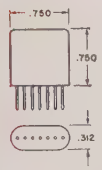
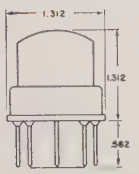


- 7 pin in-line basing
- Non polarized connected
- All welded connections
- Epoxy encapsulated with metal case
- Mates with socket — Elco type 790 BC or Cinch type 2H7 or equal

PAK STYLE 2 — MV

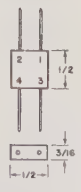


- Type MT-8 shell
- Soldered connections
- Plugs into standard 8 pin octal socket

PAK STYLE 3 — MP

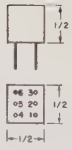
- All welded construction
- Epoxy resin encapsulant
- Basing shown bottom view
- Plugs into standard 7 pin miniature socket

PAK STYLE 4 — TK



- Pigtail leads
- Epoxy resin encapsulant
- Welded construction
- Leads 1.0" minimum length, .019" – .021" diam.

PAK STYLE 5 — TL



- Printed circuit pins
- Pin spacing on .100" grid
- Epoxy resin encapsulant
- Universal connections
- Welded connections

PAK STYLE 6 — TM

- Epoxy resin encapsulant
- All welded construction
- Each diode individually terminated
- Plugs into standard 9 pin miniature socket

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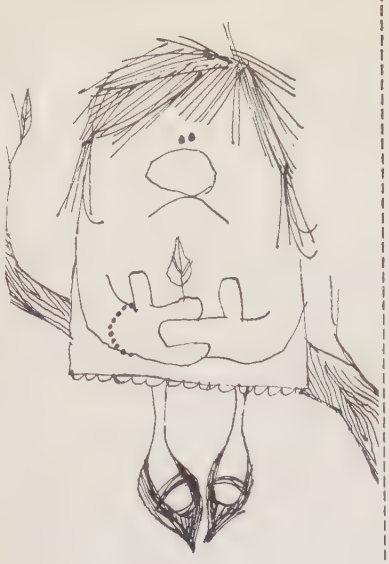

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(Continued on page 136A)

Professional Group on Electronic Computers

The electronics computer today stands as one of the most important of all engineering tools and is in widespread use in many military, industrial, and scientific applications. And yet just a decade ago, only a handful of these machines were in existence.

The field of electronic computers is thus one of the youngest and fastest growing branches of the radio engineering art. The rapid expansion of this field led to an urgent need for a means whereby the computer engineer could readily keep abreast of the many developments in this important new field.

In response to this need, the IRE Professional Group on Electronic Computers was formed in October of 1951. Interest in the Group was so great that membership has now grown to approximately 10,000.

The principal activity of the Group is the publication of TRANSACTIONS containing technical papers describing recent developments in the computer field, reviews of current literature, and news. TRANSACTIONS is published bimonthly and sent to all Group members who have paid the annual assessment of $4. Thus the Group member is provided with an invaluable source of authoritative information in his particular field of specialization.

Each year the Electronic Computer Group co-sponsors computer conferences on both the East and West Coasts, and organizes several sessions at the IRE International Convention.

In addition to these national meetings, the Group has organized some 22 Chapters all over the country which hold local meetings in conjunction with IRE Sections, thus filling out a program of technical activities which has proved indispensable to the computer engineer.

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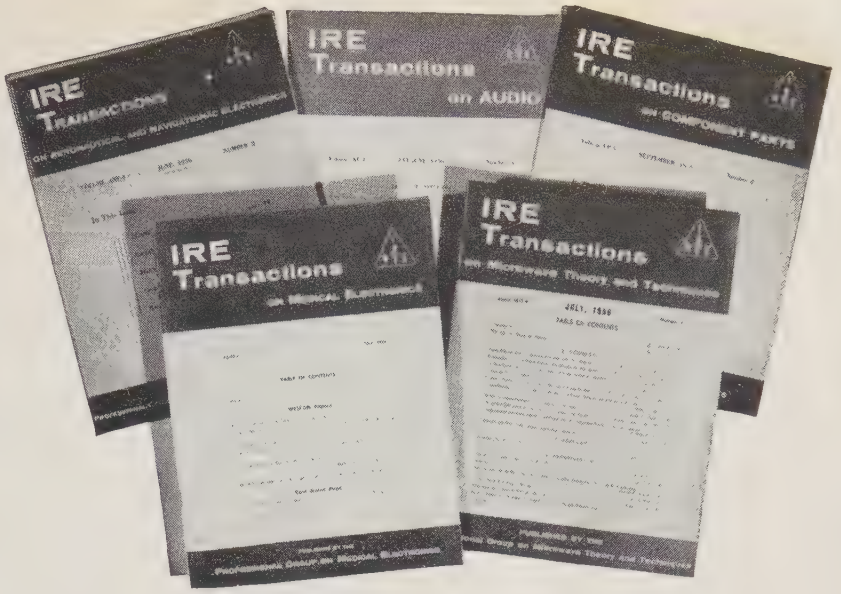

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(Continued on page 138A)

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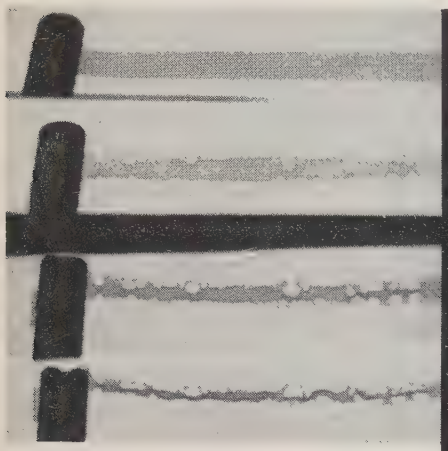

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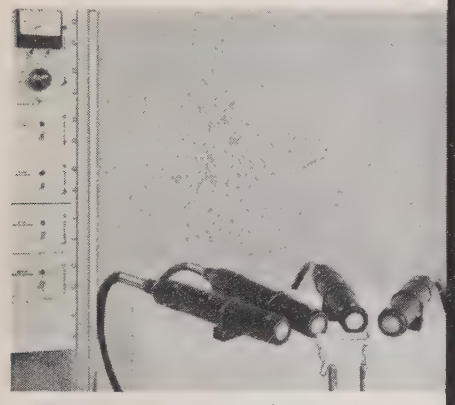

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Several tubes may be located in a small volume and flashed in sequence to avoid film motion; this system has four each tubes, pulsers and delay generators for interpulse periods from 1 to 1000 μsec; voltage 100 kv, dose rate of 10^7 rads/sec, choice of pulse lengths from 30 to 100 nanoseconds; Price $15,170.

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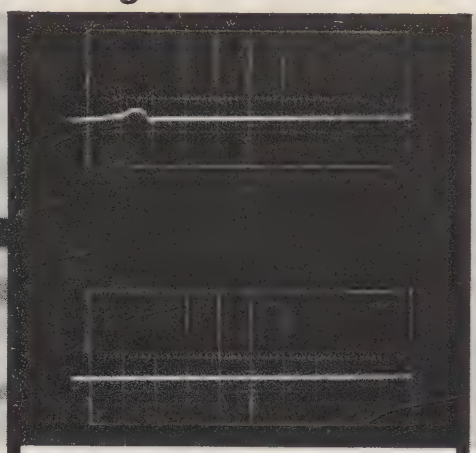
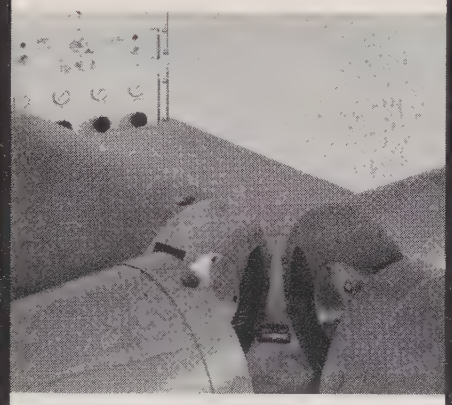


Radiation Effects:
Current of several ma induced in dielectric (capacitor) at 10^8 rads/sec; lower trace shows low noise level.



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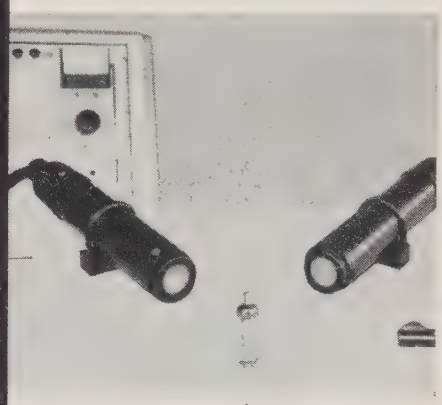

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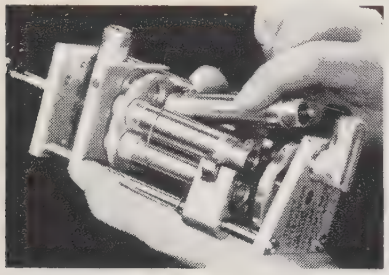
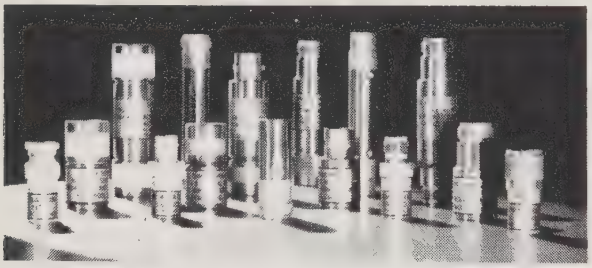
Manufactured using exclusive Stoddart film resistors for highly accurate and stable operation from dc thru 3000 mc; with special values from dc thru 10 kmc.



2, 6 and 10 position turret attenuators offer quick removal, replacement or rearrangement of single attenuator pads. **Small and rugged,** the Stoddart turrets operate with a **"Pull-Turn-Push"** sequence.



Stoddart attenuator pads are available in any value from 0 thru 60 db, including fractional values. Any conceivable combination of male and female, Type N and Type C connectors may be ordered. **Pads with flanges for panel mounting can also be supplied.**

10, 20, 40 and 60 db attenuators are available for operation from dc thru 10 kmc.

1 watt, 50-Ohm terminations can be selected for use from dc thru 7000 mc, in addition to those in the dc-3000 mc range. All 1 watt terminations can be supplied with either Type N or Type C connectors. ½ watt, 50 or 70-Ohm terminations with BNC or TNC connectors manufactured for use from dc thru 1000 mc.

Common db values available from stock.

Detailed literature upon request.
Immediate delivery from stock.

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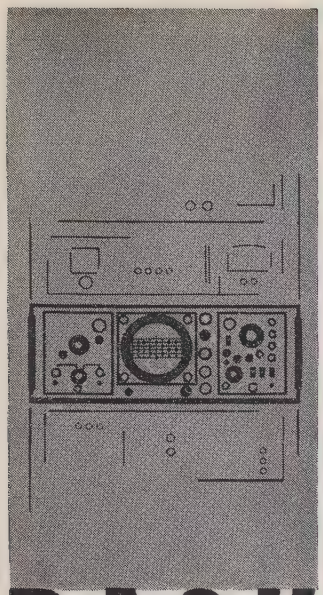
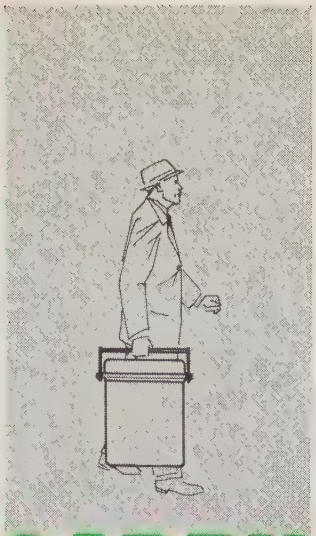


RACK

BENCH



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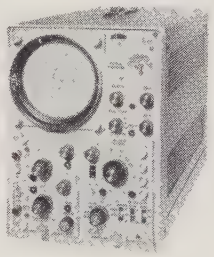
5 mv/cm
at 25 Mc...
all three versions
...10 times the
sensitivity

DU MONT 765 SERIES

THE UNIVERSAL FAMILY OF OSCILLOSCOPES

Not only superior in electronic capability . . . the Du Mont 765 Series of oscilloscopes satisfies all mechanical dimensions for rack, bench and portable applications. Smaller in size and weight than other scopes in the high-frequency range, the 765 Series gives the user 10 times the sensitivity. Such plus features as the rugged reliability of solid-state circuitry (Fairchild silicon transistors), joystick control of traces, plug-in circuits interchangeable within any of the scopes in the series—driving the CRT directly, and a larger display area—6 x 10 cm. Ask for complete details or a demonstration.

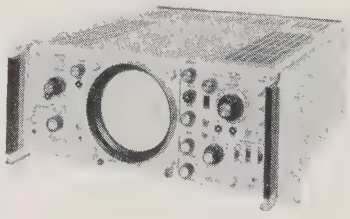


TYPE 766

TYPE 765 PORTASCOPE*

MECHANICAL SPECIFICATIONS

	765 (in case)	766	767
Length (overall)	24″	20⅝″	22⅜″
(behind panel)	–	–	20″ or 18¾″
Width (overall)	17¾″	9¾″	19″ rack or 16¾″ bench
(behind panel)	–	–	16¾″
Height	8⅛″	13¾″	7″
Weight	27 lb.	27 lb.	27 lb.



TYPE 767

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Please send detailed information on the 765 Series.

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Firm.....
Address.....
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closed-cycle
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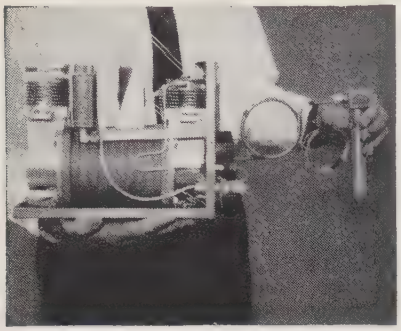
...temperatures to 80° K
...introduce no microphonics
...need no support equipment



...These original systems utilize highly developed non-lubricated compressors and Joule-Thomson cryostats. Tests on both high- and low-impedance infrared detectors show that Air Products closed-cycle coolers introduce no microphonics into IR systems.

Reliable, compact Air Products cryogenic coolers include the following advanced features:

- **Dynamic balancers** counteract reciprocating motion of compressor pistons
- **Carbon-filled fluorocarbon resin piston rings** prevent gas contamination
- **Non-orificed heat exchangers** generate no measurable microphonics
- **Sound-absorbing mounts** prevent transmission of compressor-generated microphonics along gas lines

These closed-cycle cryogenic units for IR-detector cooling weigh as little as 16 pounds... measure 5" x 8" x 12" ... provide up to 5 watts of refrigeration at 80°K. Completely self-contained, they require no external liquefiers or high-pressure gas supplies.

For your IR-cooling requirements, consider using a closed-cycle refrigerator. It will enhance your system by reducing need for ground-support equipment.

ADVANCED PRODUCTS DEPARTMENT
DEFENSE AND SPACE DIVISION

Air Products and Chemicals INC.
Allentown, Pennsylvania

▶ Air Products manufactures a complete line of cryogenic electronic coolers.

Membership

(Continued from page 138A)

Karas, C. A., Gettysburg, Pa.
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Korver, K., Den Haag, Netherlands
Kroch, R. P., Ithaca, N. Y.
Lake, A. S., Hartford, Conn.
Laufman, J. K., Whittier, Calif.
Leabman, J. I., Sharon, Mass.
Lord, W. J., North Highlands, Calif.
Maleski, L. A., Tyndall AFB, Fla.
Marcar, H., Bayside, L. I., N. Y.
Marneris, M., Cleveland, Ohio
Matheson, M. O., Lacombe, Alta., Canada
McElwain, J. C., Hansboro, Miss.
McGill, H. I., Palo Alto, Calif.
McIntyre, S. C., Altadena, Calif.
McLinskey, J. P., Sayville, L. I., N. Y.
Migliaccio, J. S., Brooklyn, N. Y.
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Morrone, V., La Guardia Airport, L. I., N. Y
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Murtagh, T. B., Washington, D. C.
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Newton, V. S., Hyattsville, Md.
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Nolder, P. J., Ben Avon, Pa.
Ofek, Y., Stamford, Conn.
O'Rourk, R. P., North Babylon, L. I., N. Y.
Pantano, P. J., Union, N. J.
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Pawlowski, W. J., New York, N. Y.
Perkarsky, W. S., Orange, N. J.
Peters, A., North Hills, Pa.
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Rish, M., Philadelphia, Pa.
Roessling, W. P., Brooklyn, N. Y.
Rumpf, R. R., San Diego, Calif.
Saunders, T. D., Dayton, Ohio
Schraut, E. M., Minneapolis, Minn.
Schwartz, R. E., Van Nuys, Calif.
Shimp, A. C., Hopkins, Minn.
Shobert, J. F., Briarcliff Manor, N. Y
Siegel, I. P., West Orange, N. J.
Silver, J. L., Yuma, Ariz.
Sindoris, J. C., West Concord, Mass.
Skenes, C. P., Charlottesville, Va.
Smoot, R. D., Erie, Pa.
Snyder, L. F., Thomasville, Ala.
Spiwak, R. R., New Market, N. J.
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Stern, R. H., Frankfurt/Main, Germany
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Thel, H. W., Burnaby, B. C., Canada
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Voronin, O., Buffalo, N. Y.
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Watjen, H. H., Jamaica, L. I., N. Y.
West, C. P., Jr., New York, N. Y.
Wilhelm, S. F., Great Lakes, Ill.
Williams, A. B., New York, N. Y.
Wilson, T. H., East Meadow, L. I., N. Y.
Woods, P. R., Grand Rapids, Mich.
Worth, J. C., Jr., Phoenix, Ariz.
Wright, R. L., Dallas, Tex.
Young, R. L., Bloomington, Ind.
Zachariah, V. N., San Francisco, Calif.
Zimmerman, W. J., Skokie, Ill.
Zytka, R. F., Commack, L. I., N. Y.

IRE People

(Continued from page 86A)

Donald B. Sinclair (J'30–A'33–M'38–SM'43–F'43), Executive Vice President and Technical Director of General Radio Company, West Concord, Mass., has been appointed to the Visiting Committee for the Carnegie Institute of Technology Department of Electrical Engineering.

D. B. Sinclair

The committee serves to familiarize leading scientists and members of industry with Carnegie Tech activities, and additionally to secure their counsel and views in achieving objectives of the Institute.

Dr. Sinclair is a Fellow of the American Institute of Electrical Engineers and was formerly President of the IRE. He received his S.B., S.M., and Sc.D. degrees from the Massachusetts Institute of Technology.

❖

The appointment of **Professor Edward J. McCluskey, Jr.** (S'51–M'55–SM'59) as Director of Princeton University's Computer Center was announced recently. Dr. McCluskey, an Associate Professor in the Department of Electrical Engineering, will

(Continued on page 142A)

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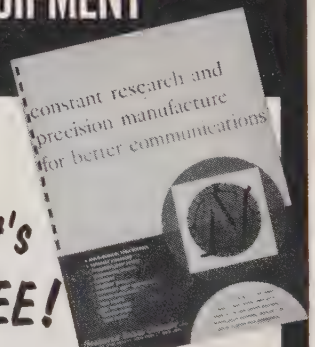

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ML-8139

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Writing Speed — at full brightness:
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Over 150,000 inches per second — ML 8139

Storage: Uniform Storage Characteristics

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Focus: — both tubes: Electrostatic

Deflection: ML-8130 — Electrostatic
ML-8139 — Magnetic

The Machlett Laboratories, Inc. announces the availability of two new Direct View Storage Tubes, ML-8130 and ML-8139. (Available also in non-shielded versions as ML-7222 and ML-7033). Ruggedized and reliable, these tubes are particularly suited for these typical applications:

Airborne	Shipboard	Ground
Weather radar	Sonar long-memory displays	Slow-scan television
Search Navigation	Marine displays	Storage instrumentation
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Write today for complete data on these new Machlett Direct View Storage Tubes.

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2000°C
HIGH POWER LOADS
AIR COOLED SERIES LISTED—HIGHER POWERED, WATER COOLED VERSIONS (DB-462) ALSO AVAILABLE
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PASADENA, CALIFORNIA, U.S.A.

IRE People

(Continued from page 140A)

continue his teaching responsibilities in addition to his new assignment.

Dr. McCluskey, an authority in the field of digital information processing systems whose research is concerned with the logical design of such systems, joined the Princeton faculty in 1959. He has designed a two-term course in the theory of these systems—one at the undergraduate and the other at the graduate level.

The University of Michigan invited him to lecture at a special summer course on the advanced theory of the logical design of digital computers in 1959, and again at a summer conference the following year. He participated in a seminar sponsored by the Radio Corporation of America in 1959, delivered a paper on "Minimization Theory" before the AIEE in 1960, lectured at the AIEE fall lecture series of 1959, and at the International Conference on Information Processing Systems.

Dr. McCluskey received his A.B. degree in mathematics and physics from Bowdoin College in 1953; and his B.S., M.S., and Sc.D. degrees from MIT. After four years on the technical staff of the Bell Telephone Laboratories, he came to Princeton and was appointed an Associate Professor after two years as a lecturer with rank of Assistant Professor.

In addition to his teaching and research he has written for professional publications. He is a member of the Editorial Board, *IRE Transactions on Electronic Computers*; a member of the AIEE Subcommittee on Switching and Logic Circuit Theory, and of the Association for Computing Machinery.

❖

The appointment of **Walter W. Smock** (M'56) as Regional Marketing Manager, Philadelphia area, for Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., has been announced.

W. W. Smock

Mr. Smoch has served as Product Manager since joining the company in July, 1961.

Prior to joining Sylvania, he was Director of Marketing for Wolf Research and Development Corp., Boston, Mass., and, earlier, Manager of Digital Communications Marketing for Radio Corporation of America, Camden, N. J.

Mr. Smock was graduated from the University of Scranton in 1948 with a Bachelor's degree in electrical engineering. He has also done graduate work in Mathematics at Villanova University.

A member of the Association for Computing Machinery, Mr. Smock is also a member of the Army Retired Officers Association, Washington, D.C.

❖

(Continued on page 144A)

RECOVER SIGNALS FROM

NEW LOCK-IN AMPLIFIER

Now you can recover signals 40 db below 1 kilocycle bw ambient white noise.

This new signal processing instrument is designed to recover signal information from noise. It is a narrow band detection device, the center frequency of which is locked to the frequency at which the signal information has been made to appear. Therefore, extremely narrow detector band widths can be obtained with complete freedom from drift between the detector center frequency and the characteristic signal frequency. Consequently, it is applicable to situations where narrow band operation will enhance signal-to-noise ratio. Lock-in amplifier techniques are being used in radio astronomy, nuclear and electron magnetic resonance experiments, carrier life time studies in semiconductors, experiments in special and general relativity, and optical pumping.

Pertinent specifications include: **frequency range** 15 to 15,000 cps continuously tunable; **equivalent band width** 0.12 cps min. (2 sec. max. RC integrating time). 6 or 12 db per octave selectable roll-off; **gain** RMS AC in to push-pull DC out — approx. 9,000. Completely transistorized. Price: $990.

Write for Bulletin 103

PAR Princeton Applied Research

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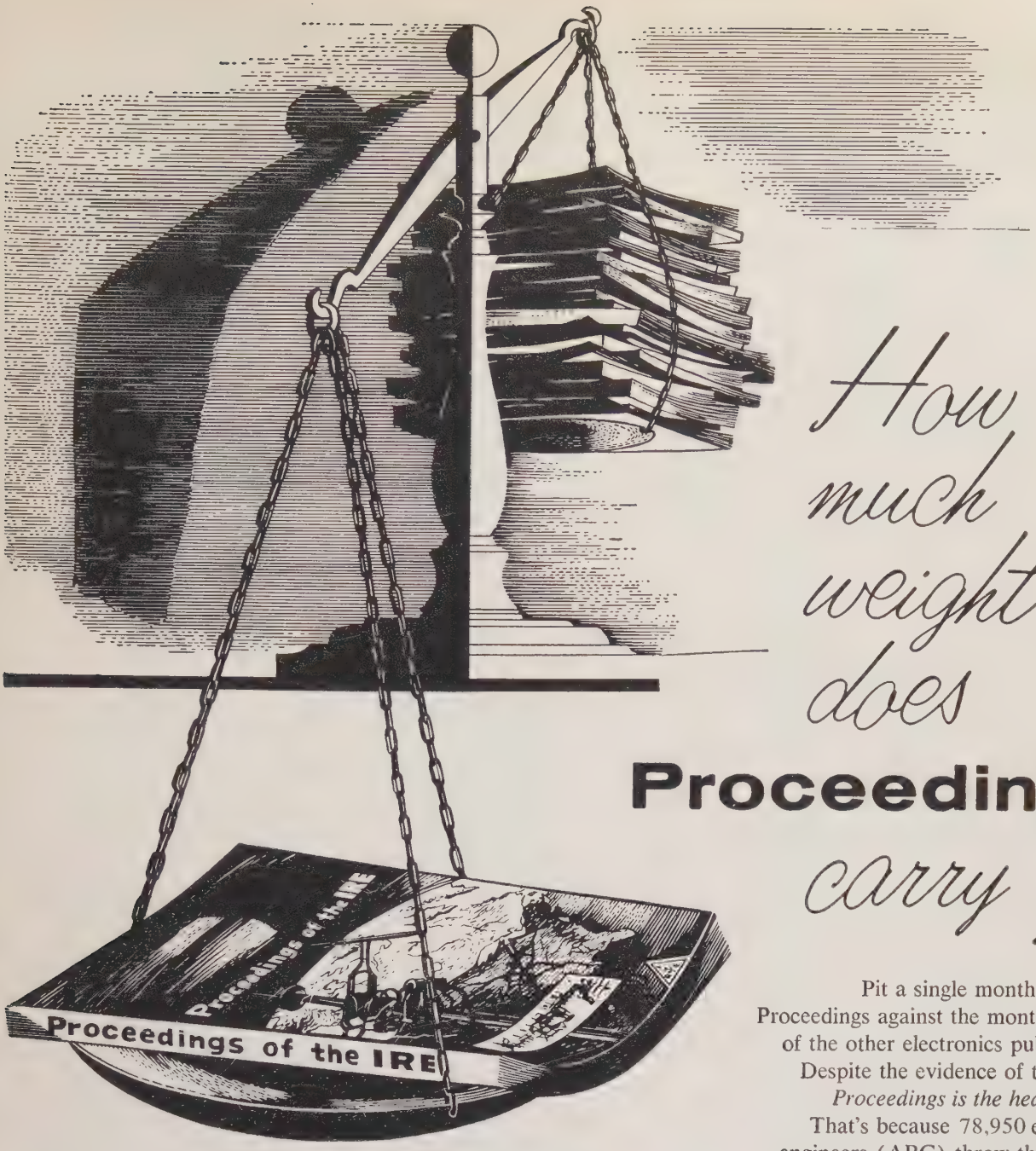

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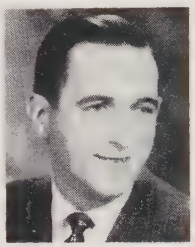
IRE People

(Continued from page 142A)

Herman Albertine, Jr. (SM'58), has joined National Electronics, Inc., Geneva, Ill. as Regional Sales Manager.

Previously Mr. Albertine was Director of Marketing for General Electrodynamics Corp., Garland, Tex. His twelve years of experience in the electronic tube business includes much work on special purpose power tubes as Chief Manufacturing Engineer at Westinghouse.



H. ALBERTINE, JR.

He earned his Bachelor's degree at Cornell University in electrical engineering. Mr. Albertine is a member of the American Vacuum Society and the American Society for Quality Control.

❖

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 58A)

Modular Power Pack Supplement

Electronic Research Associates, Inc., 67 Factory Pl., Cedar Grove, N. J., announces the availability of a technical bulletin supplement which describes the company's recently introduced 500 milliampere series of solid-state modular power packs. The technical bulletin supplement, which is designated as #27-1261-1, provides descriptive information, specification data, and related information on these new units which are available for all battery voltage outputs.

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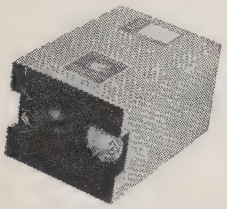

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ADVANCED THERMAL DESIGN

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TR051	0-5	0-1 amps	HA	150.00
TR052	0-5	0-2 amps	H	185.00
TR054	0-5	0-4 amps	K	275.00
TR058	0-5	0-8 amps	M	345.00

CASE SIZES
D—2⅝W x 3⅛D x 4¼H
MH—3¼W x 3¼D x 4⅝H
HA—3¼W x 4D x 5 1/16H
H—4 1/16W x 4D x 5 1/16H
K—5⅛W x 7¼D x 5¾H
M—7⅝W x 8¾D x 6 1/16H

Other modular high current units are available with voltage ratings up to 33 volts and current ratings up to 8 amperes.

*F.O.B. Cedar Grove, N. J. ®Reg. U.S. Pat. Off.

Write for complete Technical Specifications
ELECTRONIC RESEARCH ASSOCIATES, INC.
Laboratories & Factory: 67 Factory Place
Cedar Grove, New Jersey — CEnter 9-3000

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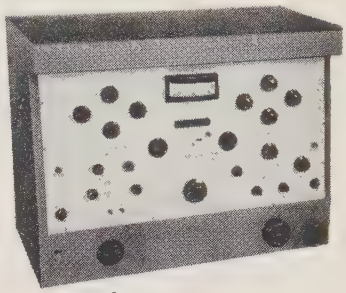
SENSITIVE RESEARCH

CONSOLES

CALIBRATION INSTRUMENTS

Model LTC-1



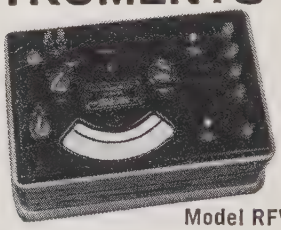
The *only* AC and DC calibration console to offer these advantages!

- **Accuracy:** ±.05% of reading
- **Frequency** Response: DC to 25 kc.
- **Current** Range: 1 ma. to 11.11 amps
- **Voltage** Range: .5 v. to 1111 v.
- **Readout** directly in "% Error."
- **Thermocouple** Overload Protection
- **Self-contained** for one man operation.

Price $5,560.00

Model LTCA-1
Same performance characteristics as Model LTC-1 above but single set of input terminals for AC/DC.
Price $4,550.00.

Model LTA-1
Hermac-type thermal transfer standard for potentiometric readout.
Price $3,150.00.



Model RFVC

RADIO FREQUENCY CALIBRATOR for the certification of VTVM's from DC to 10 mc. Accuracy ±.3% of full scale; ±.2% maximum frequency influence. Ranges .01/.1/1/3 V. Responds to true RMS. Completely "Self Checking" against an internal reference source Diamond Pivoted, of course!

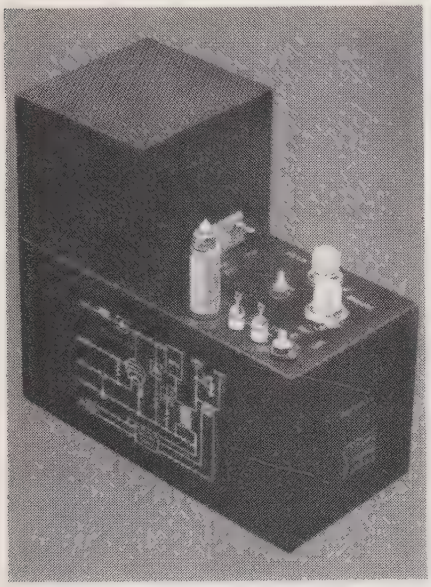
Price $840.00

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
NEW ROCHELLE, N. Y

SARATOGA INDUSTRIES REPORT

A breakthrough in Radar Modulator Design:

The **SI-7K1-U** is 40% more efficient with no change in input potential.



custom designed, engineered and produced to customer's exact specifications.

FEATURES — Exclusive fast rise technique in the PFN. Completely revised, regulated filament supply system. Gas filled to provide good dielectric strength over operating temperature range (—55° C to +100°C). Accepts short circuits and open circuits without blocking.

SPECIFICATIONS — B+1500 volts: trigger input — 200 volt peak; variable from 200 pps to 3300 pps; recovery time, 100 Microseconds; output pulse, 3½ Microseconds wide; Amplitude 7.5 KV at 1.2 Amps. with rise time less than 0.3 Microseconds.

For full information about Saratoga Industries complete design, engineering and production facilities, write

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A Division of Espey Mfg & Electronics Corp.
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ANTENNA PEDESTAL SCR 584-MP 61B

Full azimuth and elevation sweeps 360 degrees in azimuth. 210 degrees in elevation. Accurate to 1 mil. or better over system. Complete for full tracking response. Angle acceleration rate: AZ, 9 degrees per second squared EL, 4 degrees per second squared. Angle slewing rate: AZ 20 degrees per sec. EL. 10 degrees per sec. Can mount up to a 20 ft. dish. Angle tracking rate: 10 degrees per sec. Includes pedestal drives, selsyns, potentiometers, drive motors, control ampildynes. Excellent condition. Quantity in stock for immediate shipment. Ideal for missile & satellite tracking, antenna pattern ranges, radar system, radio astronomy, any project requiring accurate response in elevation and azimuth.
Complete description in McGraw-Hill Radiation Laboratory Series, Volume 1, page 284 and page 209, and Volume 26, page 233.

SCR 584 RADAR AUTO-TRACK
3 CM & 10 CM. Our 584s in like new condition, ready to go, and in stock for immediate delivery. Used on Atlantic Missile Range, Pacific Missile Range, NASA Wallaps Island, A.B.M.A. Write us. Fully Desc. MIT Rad. Lab. Series, Vol. 1, pps. 207-210, 228, 284-286.

300 TO 2400MC RF PKG.
300 to 2400MC CW, Tuneable, Transmitter 10 to 30 Watts. Output. As new $375.

AN/TPS—1D RADAR
500 kw, 1220-1359 mcs. 160 nautical mile search range P.P.I. and A. Scopes, MTI, thyratron mod. 5J26 magnetron. Complete system.

AN/TPS 10D HEIGHT FINDER
250 KW X-Band. 60 & 120 mile ranges to 60,000 feet. Complete.

AN/APS—15B 3 CM RADAR
Airborne radar. 40kw output using 725A magnetron. Model 3 pulser. 30 in. parabola stabilized antenna. PPI scope. Complete system. $1200 each. New.

10 KW 3 CM. X BAND RADAR
Complete RF head including transmitter, receiver, modulator. Uses 2J42 magnetron. Fully described in MIT Rad. Lab. Series Vol. I, pps. 616-625 and Vol. II, pps. 171-185 $375. Complete Radar System $750.

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Type CM 706A Freq. 3000 to 4000 mcs. CW. Output 200 Watts minimum. New, with full guarantee.

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1.7 to 2.4 KMC. (continuously turnable). 10 KW. CW. 50 db Gain uotput UG-435 A/U Flange $975 each.

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(A) 31 KV at 60 amps .002 Duty Cycle Ideal for 5J26 at 500 KW $950.
(B) 30 KV at 70 amps .001 Duty Cycle. $1250 w/pulse output trans.

MIT MODEL 9 PULSER 1 MEGAWATT—HARD TUBE
Output pulse power 25KV at 40 amp. Max. duty ratio: .002. Uses 6C21 pulse tube. Pulse duration .25 to 2 microsec. Input 115 volts 60 cycles AC. Includes power supply in separate cabinet and driver. Fully guaranteed as new condition. Full Desc. MIT. Rad. Lab. Series "Pulse Generators."

500 KW PULSER
5C22 Hyd. Thyr. Modulator. 22KV at 28 Amps. W/HV & Fil Supplies. 3 pulse length rep rates: 2.25 usec 300 pps. 1.75 usec 550 pps. .4 usec 2500 pps. 115V 60 cy. Will deliver nominal 225 KW X Band using 4J50 magnetron.

L BAND RF PKG.
20KW peak 990 to 104MC. Pulse width .7 to 1.2 micro sec. Rep rate 180 to 420 pps. Input 115 vac. Incl. Receiver $1200.

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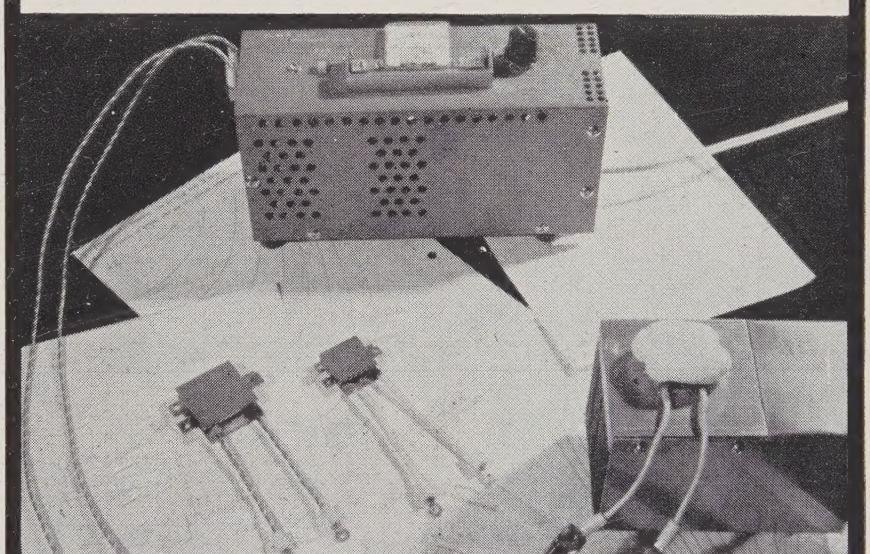
is the thermo module newly developed by Sanyo Electric Co. The technique evolved by Sanyo eliminates high cost and brittle nature of the bismuth telluride alloys used in production of thermoelements. Our exhaustive study reveals possibilities of still reducing its thinness, resulting in wider and more economical applications to scientific and electronic equipments.

SPECIFICATIONS

Type	Thermo couple	Optimum Current (amp.)	Optimum Voltage (Volt)	(1) ΔT (°C)	Insulation Voltage(2) (Volt)	Dimensions mm (inch)
STM-1025	10	25	0.9	55	50	57×43×10.5 (2.24×1.69×0.413)
STM-1021	10	21	0.9	55	50	57×43×10.5 (2.24×1.69×0.413)
STM-1016	10	16	0.9	55	50	57×43×10.0 (2.24×1.69×0.393)
STM-1012	10	12	0.9	55	50	41×32.5×9.5 (1.62×1.28×0.374)
STM-1006	10	6	0.9	55	50	41×29×9.5 (1.62×1.28×0.374)

Subject to change without notice
Note: (1) No heat load: T_h is 27°C.
(2) Voltage applied between circuit and hot or cold plate.



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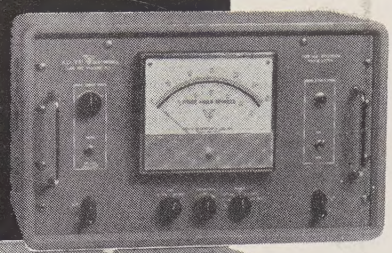
DIRECT READING PHASE METERS TYPE 405 SERIES

FEATURES

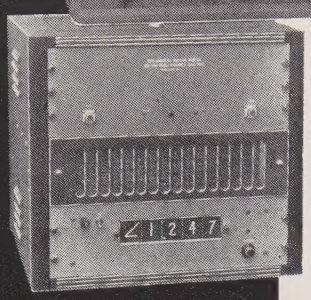
Direct reading in degrees. No amplitude adjustment, no frequency adjustment. Can be used for plotting phase frequency curves on a recorder.



SPECIFICATIONS

Frequency Response: Type 405 – 8 cps to 100 kc. Type 405H – 8 cps to 500 kc. Type 405L – 1 cps to 40 kc.
Phase Range: 0-12°, 0-36°, 0-90°, 0-180° up to 360° in eight ranges.
Input Voltage: 0.3 volt to 70 volts.
Accuracy: 0.25° relative, 1° absolute.

DIGITAL PHASE METER TYPE 524

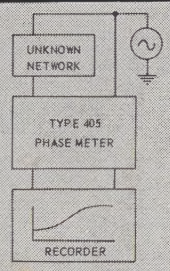


FEATURES

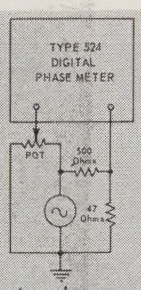
Phase angle in degrees directly represented in four digits. Phase reading independent of the ratio of signal amplitude. No frequency adjustment, no amplitude adjustment.

SPECIFICATIONS

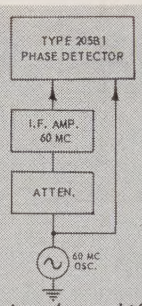
Frequency Response: 50 cps to 50 kc.
Accuracy: ±0.1° relative, ±0.5° absolute.
Input Voltage: Phase reading not affected by fluctuation of signal amplitudes from 0.3 volt to 50 volts.
Input Impedance: 3 megohms shunted by 30 uuf on both channels.



Plotting phase curve with Type 405.

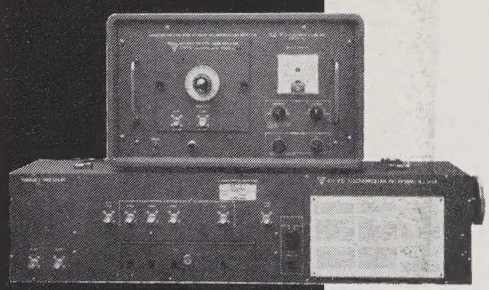


Measuring phase angle of multi-turn potentiometer with Type 524.



Measuring phase shift of IF amplifier with Type 205B1.

H-F MILLIMICROSECOND PHASE DETECTORS TYPE 205B SERIES



FEATURES

Frequency range 15 mc to 1500 mc. Accuracy 0.05° or 1%. Input sensitivity 10 millivolts with external receiver. Suitable for CW, pulse-modulated, or amplitude-modulated signal.

SPECIFICATIONS

Frequency Response: Type 205B1-15 mc to 400 mc. Type 205B2-B3: 100 mc to 1500 mc.
Resolution Time: Less than 10^{-13} second.
Characteristic Impedance: 50 ohms nominal.
Minimum Input Signal: 1 volt with panel meter.

TYPE 202: 20 cps to 40 kc. 1° full scale sensitivity. Accuracy 0.02° or 2%.

TYPE 205A1: 100 kc to 15 mc. Accuracy 0.05° or 1%.

TYPE 1002: Digital readout. 0.005 cps to 500 cps. Accuracy 0.05°.

AD-YU ELECTRONICS LAB., INC.
249 TERHUNE AVENUE — PASSAIC, NEW JERSEY
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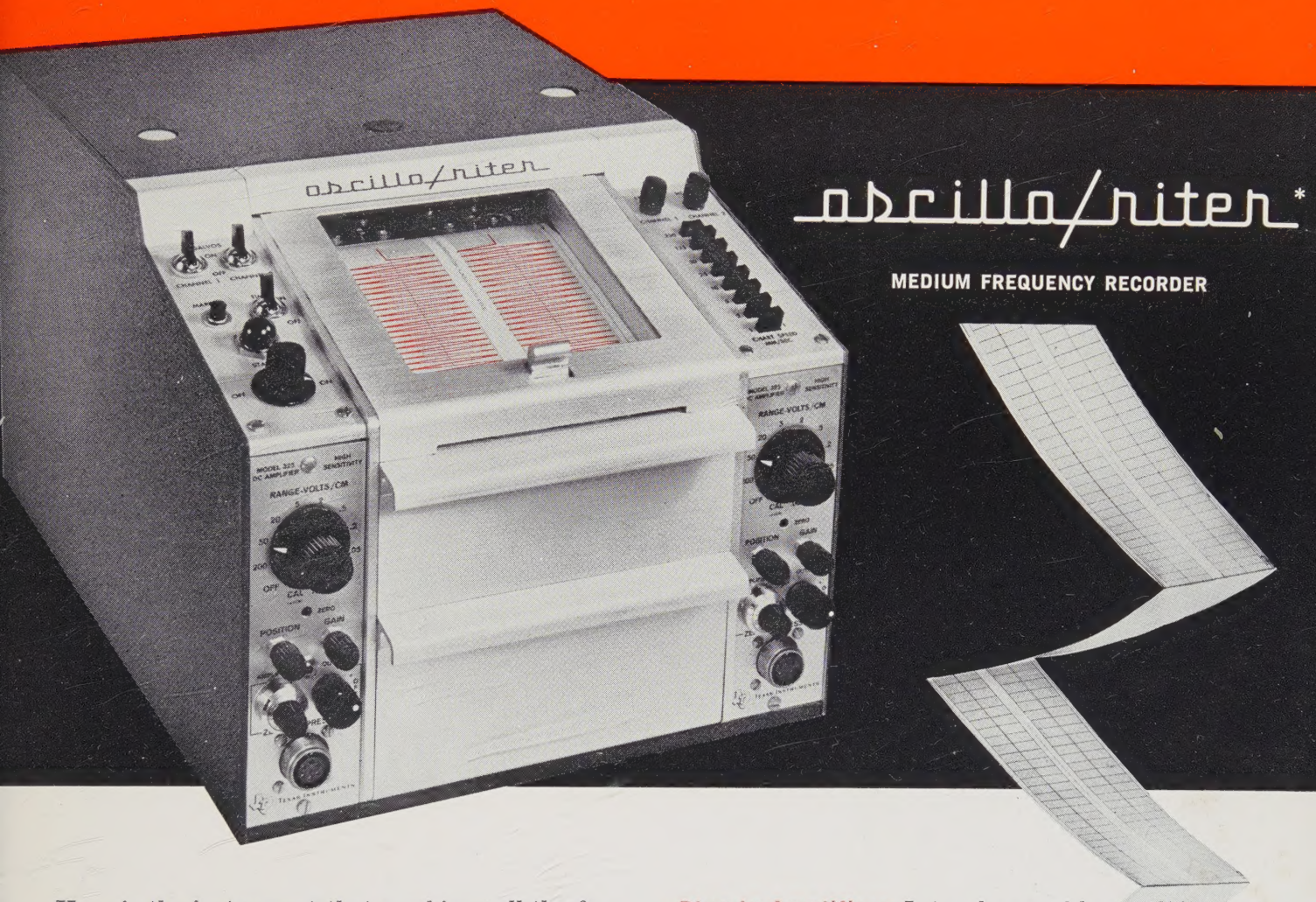
MORE OPERATING FEATURES THAN ANY OTHER MEDIUM FREQUENCY RECORDER



Here is the instrument that combines *all* the features found in other medium frequency recorders plus some TI exclusives. The *oscillo/riter* offers highest sensitivity, widest selection of ranges and chart speeds, rectilinear recording in either heat or ink, transistorized electronics, interchangeable plug-in amplifiers, and the convenience of Z-fold chart paper.

Broad Frequency Response. Flat to 200 cps within 1 db, 10 mm peak to peak with ink writing system.

High Sensitivity. Sensitivity range with high-gain amplifier is 0.5 mv/mm to 200 V/cm in 10 steps.

Push-Button Chart Speeds. Eight push buttons select 1, 2, 5, 10, 25, 50, 125, and 250 mm/sec.

Plug-In Amplifiers. Interchangeable amplifiers offer complete flexibility to economically handle more recording jobs. All electronics are fully transistorized for long-term reliability and convenience of no warm-up time.

Z-Fold Chart Paper. Provides random access to minutes, hours or days of recorded data by simply flipping pages of the chart as you would pages of a book. Roll chart paper optional.

Compare feature for feature, and you'll choose the *oscillo/riter* from industry's most complete line of strip chart recorders . . . made by Texas Instruments.

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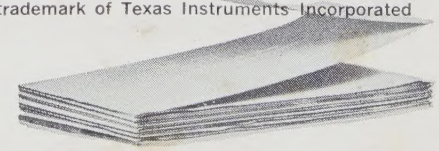

TEXAS INSTRUMENTS
INCORPORATED
3609 BUFFALO SPEEDWAY
P. O. BOX 66027 HOUSTON 6, TEXAS

NEW

SOLID-STATE COUNTER

Type 1150-A Digital Frequency Meter . . . $915

A low-cost, general-purpose digital counter for measuring frequencies, counting random events, and for industrial counting applications. The counter can be started, stopped, and cleared by external signals or manually.

The 1150-A Counter uses simple ring counting circuits which drive the readout directly. This is contrasted with other counters that use decades requiring feedback techniques, decoding matrices, and amplifiers . . . economically necessary for high-frequency applications, but overcomplicated for low-frequency measurements.

GENERAL SPECIFICATIONS

Frequency Range: 10 cps to 220 kc
Accuracy: ± 1 count ± time-base stability
Time-Base: Internal 100-kc crystal oscillator with ½ ppm stability.
Provision for external 100-kc time base
Sensitivity: Better than 1 volt, peak-to-peak. For pulses, duty ratio should be between 0.2 and 0.8. Input impedance is 0.5 MΩ shunted by less than 100 pf
Gate Times: 0.1, 1, and 10 seconds. Also manual start/stop
Reset: Automatic or manual
Display Time: Adjustable from 0.1 to 5 seconds, or infinite
Self Check: Has provision for counting own 100-kc frequency
Small Size: Only 3½" x 19" x 10"

- Totalizes events or measures frequency to 220 kc.
- New, brilliant, always in focus, NUMERIK* in-line display. 120° viewing angle . . . 5000-hour lamp life in counting service.
- Oven-controlled 100-kc crystal oscillator with ½ ppm stability. Temperature stability better than 5 ppm over an ambient range of 0° to 50°C.
- Fail-safe ring-counting circuits eliminate fussy feedback codes and critical voltage levels.

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